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THE BREAKDOWN OF HIGH POLYMER MOLECULES

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MOST complex molecules are subject to breakdown if they come under the influence of elevated temperature, visible, ultra-violet, and shorter wave radiations such as X-rays, severe mechanical shock, and by the action of specific chemical agents. When the molecular weight of the substance is of the order of that usually encountered in organic chemistry, it is sometimes difficult to detect the small amount of chemical change that occurs under the influence of the agents listed above. On the other hand, when the molecule comes into the high polymer category, *i.e.* with molecular weights varying say from 10^4 to 10^6, these effects are very much magnified, because the fission of a few linkages is readily detectable by the relatively large diminution in molecular weight that accompanies it. For this reason alone the study of the degradation of high polymers of known structures has a particular interest. However, although the general structure of a high polymer may be known, some of the less accessible, but nevertheless important, details may be unknown. Accurate studies on degradation processes may well provide a means for studying such structural irregularities.

The mechanism of breakdown will depend a great deal on the general chemical structure of the polymer. Very broadly, for the present discussion, there are two types : (*a*) those polymers containing ester, amide, etc., links which may be severed by hydrolytic agents, and (*b*) those polymers made of carbon chains or mixed groups of atoms which cannot be broken down except by much more drastic chemical treatment capable of breaking relatively strong bonds. Both these types are subject to thermal breakdown, usually into a complex variety of fragments, and if oxygen is present degradation may be accelerated. Similarly in solution both types, if they are of sufficiently high molecular weight, can be broken cleanly into smaller polymers if the solutions are subjected to a high

enough shear. Presumably this is purely mechanical, in spite of the fact that the strength of the bonds broken may amount to as much as 70 kcal. for a carbon–carbon bond. Although considerable energy may be dissipated in a highly sheared liquid, it is surprising that localisation is so marked as to produce bond fission. Similarly the high degree of shear created in a liquid by its exposure to ultrasonic radiation will bring about bond fission.

The progressive hydrolysis of cellulose was studied many years ago (Hopff, Mark and Meyer, *Berichte*, 1929, **62**, 1103). It appeared that in the initial stages of the breakdown all the hydrolysable links were equally readily attacked, but that as the degradation proceeded there was preferential attack at the terminal glucose residues, which would result in an abnormally high percentage of glucose being produced. Further study, with modern instruments for measuring molecular weights, has not proceeded. While it is well known that relatively small amounts of water will readily hydrolyse super esters, no quantitative work has been done to elucidate the mechanism. In a similar way those polymers with carbon atom backbones, such as the ethenoid polymers, can readily be degraded in solution by radical producing substances such as peroxides. In fact this is a very convenient way in which to break down such high polymers to any desired molecular weight. The mechanism of breakdown is unknown. It may be that the radicals from the peroxide remove a hydrogen or other atom from the polymer; the resulting polymer radical is then so unstable that it immediately breaks—a radical remaining and a stable, though smaller, polymer having simultaneously been formed.

In the thermal breakdown of certain ethenoid polymers, notably polymethyl methacrylate, polystyrene, poly-α-methylstyrene, quite a different behaviour is exhibited. While the polymer usually undergoes a diminution in molecular weight on heating, there are evolved simultaneously large amounts of monomer, and sometimes dimers and trimers. An additional type of mechanism must therefore come into play to produce monomers in quantities far exceeding those that would be predicted from any theory involving the fission of bonds arbitrarily along the chain. It is useful at this stage to examine the consequences of a number of mechanisms that might be suggested to explain this result, and thus to see how the experimental evidence can be used to decide between them. In Fig. 1 the molecular weight of the polymer is plotted as a function of the percentage degradation to monomer. If the polymer chain were to undergo fission at arbitrary points, the molecular weight would fall towards that of the monomer before any appreciable amount of

monomer was produced by any other mechanism. If, however, for some reason degradation consisted in the successive removal of monomer units from the end of a polymer in a series of reactions of precisely similar type—a sort of step-wise degradation—then the molecular weight of the residual polymer, it being assumed that the monomer is continually removed, would fall proportionately with the production of monomer. On the other hand, if fission of the polymer occurred into radicals and it is assumed, in accordance with the known instability of large radicals, that monomer units are easily and rapidly removed from the polymer radicals once initial fission has occurred, that particular polymer molecule would be completely removed from the system. Since fission is equally likely for all
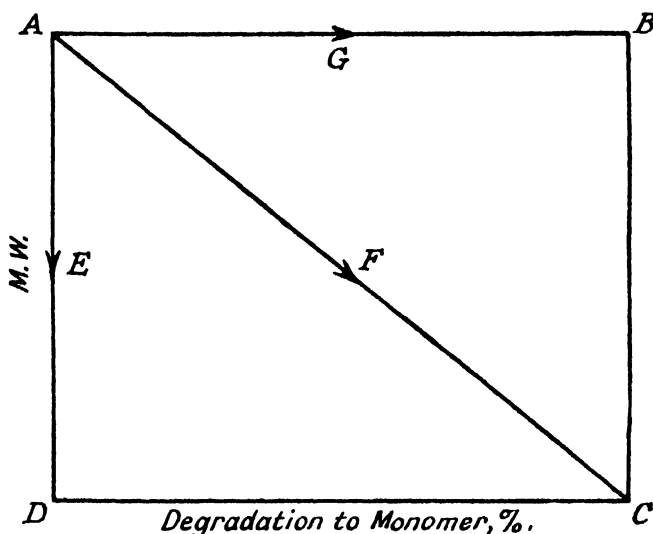
Fig. 1.

molecules, if they are similar structurally, the net result is that the *number* of polymer molecules will decrease but the average size of the remainder will not change. Some actual results are shown in Fig. 2 (Grassie and Melville, *Proc. Roy. Soc.*, in press) with poly-methacrylate. The results do not depend on the temperature at which degradation is carried out, but it is usually convenient to work between 200° and 250° C. As will be seen from the diagrams, the results depend very much on the molecular weight of the polymer. At the lowest molecular weights this magnitude remains reasonably constant throughout the course of the reaction. This means that fission into radicals occurs and that a chain-type of degradation ensues. In fact, this process is similar to polymerisation, except that it occurs in the reverse direction. No other mechanism will

fit these facts. Going to the other end of the molecular weight scale, the points lie on the diagonal of the diagram, which would indicate a step-wise mechanism. There is, however, another possible explanation. If the radical mechanism operates as before, but the polymer radicals interact with each other before the radicals are eliminated from the system, then the molecular weight of the residual polymer will decrease. This modification in mechanism would seem to become more important as the size of the radical is increased. Now, the number of polymer molecules will thus remain constant but they will decrease in size. Polymers of intermediate
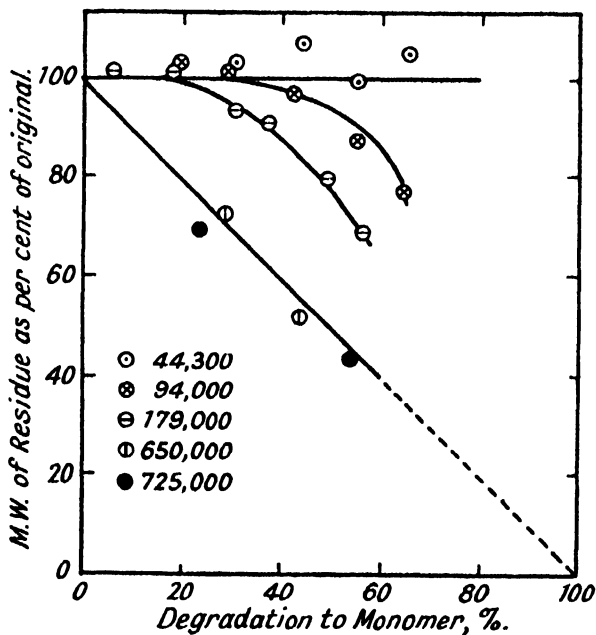
Fig. 2.

molecular weight will give results that lie between these two extremes.

While these results are fairly conclusive, it is necessary to obtain independent evidence of the operation of this " zipper " or chain-like mechanism for the production of monomer. Early in the development of the theory of chain reactions one of the strongest experimental pieces of evidence was the specific inhibitory effect of small quantities of added substances. Fortunately the same methods may be used in this case. The number of inhibitors is severely limited but certain anthraquinone dyestuffs, such as 1 : 4 diamino-anthraquinone and also their leuco compounds, function satisfactorily.

Addition of quantities of 1 per cent. by weight practically stop production of monomer altogether. Smaller quantities merely retard the rate of monomer evolution. With the leuco compounds the dyestuffs are simultaneously produced, but this is probably a secondary reaction due to the reduction of monomer. Unfortunately the addition of the dyestuff does not give rise to a well-defined induction period, and thus it is impossible to compute the rate at which bond fission occurs. Nothing is known of the point of attack on the anthraquinone molecule, but the number and size of the polymer molecules remain constant in presence of sufficient dye. Bond fission cannot be affected by such small amounts of dye, and hence it must be supposed that the dyestuff becomes attached to the radicals, thus stabilising them and preventing rapid degradation.

The next problem is to determine the point at which thermal fission of the polymer occurs : it might occur at any arbitrary point along the chain, at specially weak points or maybe at the end of the molecule. The effect of molecular weight on the rate of monomer production provides the clue. For a given weight of the same type of polymer this initial rate is independent of molecular weight, but when the latter exceeds about 500,000 the rate exhibits a distinct fall and at 700,000 is about half that for smaller molecular weights. This means that fission occurs at the *end* of the polymer molecule. Thus, as the molecular weight increases, the chain-length for the degradation increases linearly, but for a given weight of polymer the number of terminal groups *decreases* linearly. The two balance. As has already been seen with the larger polymer, the large radicals are not completely eliminated, and hence the number of monomer units produced per initial act of fission is rather smaller than the degree of polymerisation would imply.

An examination of the energetics of the process is also in general agreement with the picture sketched above. By measuring the rate of monomer production as a function of temperature and applying the usual Arrhenius relationship, the energy of activation is calculated to be 32 kcal. per mole for the initial stages of the reaction. This energy is equal, according to the above hypothesis, to the energy required to produce radicals. It is known however that the energy required to break a normal carbon–carbon bond is 70 kcal. In polymethyl methacrylate there is known to be a certain amount of strain in the polymer because the heat of polymerisation is only 11 kcal. instead of a more normal value of 17 kcal. Hence the weakest bond along the chain might be as low as 65 kcal. On the other hand, the splitting of a small radical from the end of the

polymer may be accomplished more readily if the small radical is of an appropriate structure. Another check may be made about energetics. The criterion for a chain reaction is that the energy needed for the first step should be much larger than that for the propagation step—in this case the elimination of a monomer unit from the polymer radical. This latter value can be calculated in the following fashion. It is the sum of the heat of polymerisation (11 kcal.) plus the energy of activation for the addition of a monomer molecule to a polymer radical. By separate experiments this is estimated to be about 5 kcal. Thus the reverse process will have an activation energy of 16 kcal., a figure considerably lower than the figure of 32 kcal. Even with the high molecular weight polymer the overall figure is also 32 kcal. This is to some extent fortuitous. In this case the rate of evolution of monomer is not determined by the product of the rate of initial fission and the degree of polymerisation of the resulting radical. The number of monomer units eliminated will be determined by the relative velocities of the elimination of a monomer unit and of the interaction of polymer radicals. Without going into details, it can be shown that the energy of activation of this process should be that for monomer elimination —16 kcal.—plus half that for initial bond fission—32 kcal. The total is thus 32 kcal. In a way this is unfortunate for it prevents a direct experimental determination of the energy needed to eliminate a monomer from the radical.

With most methacrylate polymers the rate of evolution of monomer falls off very rapidly—far more rapidly than would be expected from the diminution in the weight of the polymer. Measurement of the temperature coefficient of the reaction throughout degradation indicates that the energy of activation increases from 32 kcal. to nearly 40 kcal. It is this rise in energy that is responsible for the fall off in rate. At first sight it would seem that heating the polymer must transform it into a more stable modification. But this is not the true explanation. Since initial fission occurs at the end of the molecule, presumably the character of the end groups will affect the velocity of the fission process. For example, if a polymer is made by illuminating the monomer with ultra-violet light instead of using peroxide as initiator, the rate of monomer evolution is increased by 50–100 per cent. This observation gives a clue to the relative stability of the end groups. In a peroxide polymer there are no less than three types of end group. Assuming that phenyl radicals initiate polymerisation, one terminal structure will be $C_6H_5.CH_2-\overset{\displaystyle |}{C}(Me)(COOMe)$. At the other end of

the molecule there are two structures. So far as is known, it is believed that when the polymer radicals interact to terminate polymerisation they do so by disproportionation, thus

$$2R\text{---}\{CH_2\text{---}C(Me)(COOMe)\}_n\text{---}CH_2\text{---}\underset{\underset{Me}{|}}{\overset{\overset{COOMe}{|}}{C}}\text{---}$$

$$= R\text{---}\{CH_2\text{---}C(Me)COOMe\}_n\text{---}CH\text{---}C(Me)COOMe$$
$$+ R\text{---}\{CH_2\text{---}C(Me)COOMe\}_n\text{---}CH_2\text{---}CH(Me)COOMe$$
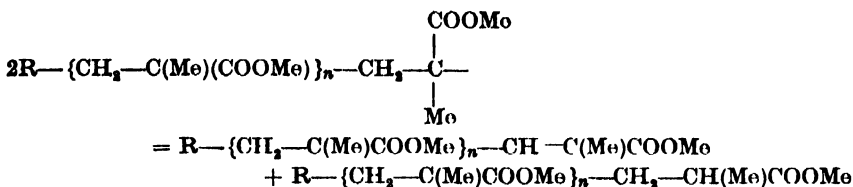
If the polymer is formed by the action of ultra-violet radiation, it is believed that a diradical is created which probably grows at both ends, each radical end ultimately undergoing disproportionation. Thus the photo polymer is similar to the peroxide polymer except that there are no terminal phenyl groups. The fact that the photo polymer decomposes more quickly would indicate that fission preferentially occurs at the ends formed by disproportionation, and, since there are twice as many ends of this kind in the photo polymer, decomposition should be twice as fast. Which group is the easier to eliminate is difficult to decide, but one is presumably easier to eliminate than the other. Since the energy for bond fission rises from 32 to 40 kcal., it would appear that the rise is due to the elimination of the less strongly bound groups, followed gradually by fission of the stronger bonds. If the nature of the end groups is completely altered by inducing polymerisation by means of diphenyl-cyano methyl radicals, then by using high enough concentrations these radicals not only start polymerisation but also stop it. A kind of molecular sandwich is made of the following structure $Ph_2C(CN).\{CH_2.C(Me)COOMe\}_n.C(CN)Ph_2$. There is now only one type of terminal group and when this kind of polymer is decomposed the rate does not fall off except in proportion to the amount of polymer present, that is the rate of bond fission is independent of the percentage degradation. Similarly the energy of activation remains constant at the much higher figure of 47 kcal. This provides additional proof that the nature of the terminal groups wholly determines the stability of the polymer.

A drastic modification can be made to the structure of the polymer by crosslinking it to a three-dimensional net-work. This is most easily done by copolymerising the methacrylate with glycol dimethacrylate. The curious result is that, even although there is one crosslink to every 10 methacrylate units and the polymer is infusible, the velocity of depolymerisation is unaffected. This simply means that the " zipper " mechanism operates unimpaired

and that thermal degradation breaks down the net-work ultimately into soluble and volatile materials.

While terminal groups have a profound effect on the stability of the polymer, the other question arises as to whether a structural irregularity, such as the introduction of other units into the polymer chain, itself interrupts the smooth flow of the " zipper " reaction. In order to synthesise such structures it is essential to choose a substance which will copolymerise with methacrylate and have a sufficiently high thermal stability. Such a substance is acrylo nitrile (CH_2=CH.CN). It copolymerises readily, and the pure polyacrylo nitrile is thermally much more stable than the methacrylate, and at elevated temperatures it breaks down into a complex variety of products. The introduction of even small amounts of acrylo nitrile, *e.g.* 1 in 500 of the methacrylate units, into polymers of a molecular weight of 700,000, *i.e.* 7000 units, has a most profound effect. Under normal conditions monomer evolution is stopped altogether, but this apparent inhibition is only temporary, for after expiry of an induction period monomer evolution starts, increases, and then diminishes towards the end of the degradation. This would mean that terminal fission of the copolymer still occurs, but, when the polymer radical degrades to the stage at which an acrylo nitrile is encountered, the process comes to a complete halt and the temperature of the system must be raised if degradation is to continue, even though a free radical is involved. There is even a more surprising effect. If the molecular weight of the polymer is measured during the course of the induction period it shows a rapid diminution to a limiting value. For, with an acrylo nitrile methacrylate ratio of 1 : 400, the limiting molecular weight turns out to be about 40,000—*i.e.* a degree of polymerisation of 400—exactly the average distance between the acrylo nitrile units. The introduction of this type of irregularity thus serves to cause the polymers to split into smaller polymer *molecules*, the size being determined by the distance between the acrylo nitrile units. Once this process is completed during the induction period, these smaller polymer molecules then proceed to degradation by terminal fission, followed by the " zipper " mechanism.

Referring back to Fig. 1, this latter type of mechanism would thus follow ideally the vertical line at the left of the diagram. Only the step-wise mechanism remains, but this would really be a limiting case of the mechanism of degradation occurring with the larger molecules. At least three kinds of mechanism of polymer degradation can occur. Polymethyl methacrylate exhibits all three in suitable circumstances. Presumably other polymers will behave in

a similar fashion, provided, of course, polymer radicals formed in these thermal processes can smoothly eliminate monomer molecules without the expenditure of unduly large amounts of energy.

Finally something may be said about the degradation brought about by supersonic radiation. Nearly all the observations have been made at normal temperatures around 25° C., where radical breakdown cannot occur owing to energetic requirements. Provided the molecular weight of the polymer is high enough, that is over 100,000, then solutions of it exposed to supersonic radiation will degrade in a matter of hours. Degradation is most vigorous when cavitation is allowed to occur in the liquid. Here however the liquid is so violently agitated that it would appear that the degradation is due to mechanical effects similar to those that might be obtained by violent stirring or ejection of the solution from small orifices. Furthermore the presence of oxygen can well upset the mechanism of degradation under these conditions. These cavitation effects can be eliminated by keeping the solution under pressure or by working *in vacuo*. In either case degradation is still observed but the effect is very much diminished. There is no question that the radiation is absorbed and presumably the liquid is subjected to considerable shear. The number of polymer molecules in solution from time to time then increases, as shown most clearly from osmotic pressure experiments (A. J. R. Murray, unpublished). Therefore the problem arises as to how the covalent links in the molecule are broken. As in the thermal degradation it might be expected that radicals would be produced. The simplest and most sensitive way of detecting radicals is to conduct the degradation using a monomer as solvent. If radicals are produced, then polymerisation of monomer should be induced and the number of polymer molecules would then *increase*. When a great variety of polymer-monomer systems of this kind are so investigated there is no inducement of polymerisation which implies that the polymer molecules break down predominantly in *molecules*. If radicals are in fact formed, it would appear that they undergo disproportionation as, maybe, energetically the most economical way of molecular degradation. Even a molecule, such as the acrylo-nitrile methyl methacrylate copolymer which is weak thermally, does not undergo supersonic degradation any faster than pure polymethacrylate. This would seem to indicate that supersonic fission of a polymer does not necessarily proceed at the weak points. What is not clear is precisely how the energy transmitted to the liquid from the activating source enters the molecule and becomes so concentrated that it is capable of breaking quite strong bonds between atoms.

THE MINERALOGY OF ARENACEOUS DEPOSITS

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In this account of some recent developments resulting from the microscopical examination of sand-containing deposits, it is proposed to review the work carried out by sedimentary petrologists and soil mineralogists during the last fifteen years. It will be necessary, however, to begin with a short survey of earlier work.

In sands and sandstones the grains are of such a size (av. 0·1 to 1·0 mm.) that they can be studied and identified without elaborate preparation. Some work of this nature was done over 100 years ago, but from about 1870 onwards the newly developed method of studying rocks in thin section was occupying the attention of petrologists. In thin section the crystalline (*i.e.* igneous and metamorphic) rocks showed interesting structures and varied assemblages of minerals such as quartz, colourless alumino-silicates (felspars, felspathoids, white micas) and ferro-magnesian silicates (amphiboles, pyroxenes, dark micas, olivine) ; whereas in sandstones the structures were monotonously alike and often no mineral other than quartz could be identified. Hence, for some decades the crystalline rocks were assiduously studied and sandstones were neglected.

Methods of immersing sands or crushed rocks in heavy liquids to separate quartz, felspar, etc., from minerals of higher density were developed during the latter part of the nineteenth century. A few ounces of crushed sandstone yielded a residue of heavy minerals, often small in amount yet showing a much larger assemblage of species than was encountered in thin sections, the reason being that the quantity of the sample was many thousands of times greater than the quantity of rock in a thin section. The minerals most persistently present in such residues were not the *commoner* heavy minerals of crystalline rocks, but the *rarer* ones (zircon, $(Zr,Hf)SiO_4$; rutile, TiO_2 ; etc.). It was observed that sedimentary formations were often characterised by particular heavy mineral assemblages,

which might be used to identify the formations much in the same way as fossils are used. Such correlation often remained valid over considerable areas ; but there was always some lateral variation, which, if sufficiently large, might provide evidence concerning the source of detritus and the palæogeography of the period represented. These promising methods were soon widely employed by academic research workers, petroleum geologists engaged in mapping un-fossiliferous deposits, pedologists interested in the mineralogy of soils, and others. Fuller accounts of these developments have been given by Boswell (1933) and Milner (1940).

The facts and conclusions thus accumulating needed critical examination and probably the first comprehensive review was that made by Boswell (1933), who set out clearly the trends of thought then current and exposed gaps in our knowledge. One question
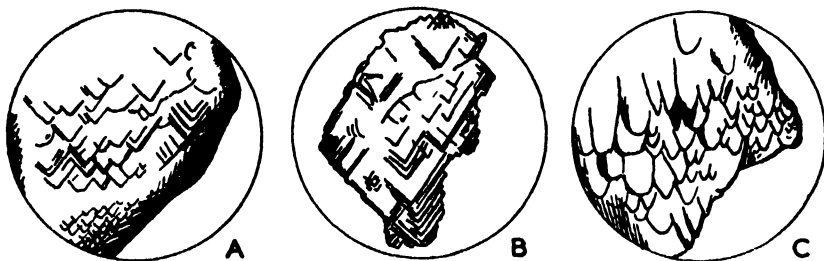
FIG. 1.

A. Garnet, naturally etched, Glacial sand, Anglesey (× 200).
B. Garnet, naturally etched, Jurassic, Yorkshire (× 150).
C. Garnet, etched with hydrofluoric acid (× 200).

which was shown to require further research was that of the stability of detrital minerals in sediments.

That mineral grains in sands and sandstones decompose after deposition of the sediment was clearly recognised. The presence of " ragged " or " etched " grains was known to be common in such species as garnet (Fig. 1A and B), staurolite, amphiboles and pyroxenes, and seemed attributable to decomposition and solution (Edelman, 1932 ; Edelman and Doeglas, 1934), though some petrologists favoured the views that such forms were due to secondary growth or to abrasion during transport. These apparently trivial features had thus assumed considerable theoretical and practical importance. If the minerals exhibiting them are in the process of being dissolved, it may be inferred that these minerals will ultimately disappear and consequently that many sediments now poor in mineral species formerly possessed richer assemblages. Sediments which contained few mineral species had formerly been

thought to consist of material which had been " re-worked " several times, so that the less stable minerals had been lost during successive episodes of erosion and transport. It is possible to admit this explanation in some cases and yet recognise that solution after deposition may be true in others. In his Presidential Address to the Geological Society in 1941, Boswell (1942) again dealt with this problem, claiming that sufficient evidence had accumulated to establish the " solution hypothesis," and suggesting the need to review critically some of our earlier assumptions which had been based upon erroneous conceptions of mineral stability, a view to which still later work lends further support.

There is, first of all, a little experimental evidence. Artificial abrasion tests have been carried out by several workers but none appears to report the production of grains of the type in question. Thiel (1940), for example, has churned minerals in water for considerable periods and in all cases his photomicrographs show progressive rounding, not the development of ragged surfaces. Chemical action, on the other hand, is capable of producing etched surfaces similar to those observed on natural mineral grains. On garnet, as Bramlette (1929) showed, the phenomenon can be produced by treatment with hydrofluoric acid (Fig. 1c). That less potent solvents, given thousands or millions of years, are capable of producing similar results seems a reasonable surmise, but one which we cannot put to experimental test. It is necessary to seek a less direct method of approach.

Bramlette (1941) has thrown further light on the problem by describing sandstones of Tertiary age, in which hornblende and epidote are scarce and show what he describes as " cockscomb terminations " ; but in parts of the sandstone, where the grains are more compactly cemented together to form concretions, hornblende and epidote are relatively abundant and show no signs of the corrosion which has affected the grains in the more porous parts of the rock.

The Mesozoic sandstones of Yorkshire (especially the Middle Jurassic) yield assemblages of heavy minerals very suitable for the study of this phenomenon, for they show decisive lateral variations in mineral composition and in degrees of " etching " for which the " solution hypothesis " seems the only plausible explanation (Smithson, 1939, 1941, 1942). In the southern outcrops a large number of mineral species is present, and most of them (garnet, staurolite, etc.) occur as smooth-surfaced grains, only kyanite being etched. Farther north kyanite is absent, and garnet and staurolite are etched. Still farther north, staurolite is absent ; and so the

assemblage gradually changes until, in the central region, kyanite, staurolite, and garnet are all absent and the total number of detrital minerals present is extremely small (Fig. 2).
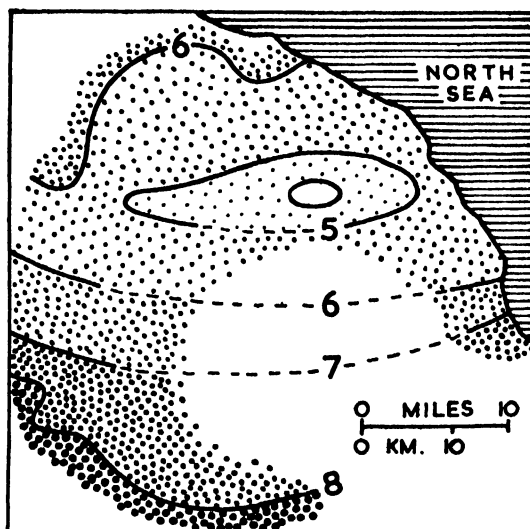
FIG. 2.—Map showing richness of heavy mineral assemblages in part of the Jurassic system in Yorkshire.

(The numerals indicate the number of non-opaque heavy minerals.)

Assuming that the etching is entirely due to decomposition in the period during which these deposits have lain buried,* and that the present distribution of minerals has been largely determined by the same cause, it has been possible to arrange the minerals of these rocks in a series so as to indicate, in a general way, their relative stability (Table I, fourth column).

It is instructive to compare this stability series with those obtained by other methods. Of the seven series shown in the table, the most comprehensive and probably the most objective is that of Pettijohn, here given in an abridged form. Investigating the well-known fact that present-day sediments are on an average richer in mineral species than those belonging to earlier formations (Fig. 3), he collected published records of minerals in sediments of all ages and countries. Thus he obtained for each species, (1) its frequency

* Weathered specimens, which are normally avoided in this work, exhibit mineral changes evidently produced in recent times by atmospheric agencies. In such specimens apatite is particularly liable to show signs of attack, although in unweathered ones it shows none even where garnet has been attacked.

TABLE I

THE STABILITY OF HEAVY MINERALS

Mechanical Action.	Chemical and Mechanical Action.	Chemical Action.				
Abrasion Tests.	Marine Shore Sands.	Subterranean Strata.		Weathering(?).	Weathering of Rocks and Soil Minerals.	
Freise (1931).	Thoulet (1913).	Pettijohn (1941).	Smithson (1941).	Sindowski (1949).	Goldich (1938).	L. and C. Dryden (1946).
		Rutile				
	Zircon	Zircon	Zircon	⎰Zircon		Zircon
	Rutile		Rutile	⎱Rutile		
Tourmaline		Tourmaline	Tourmaline	⎱Tourmaline		Tourmaline
		Monazite	Apatite			Monazite
Staurolite			Monazite			
Augite						
Garnet	Biotite	Garnet	Garnet		Biotite	
		Biotite				
Olivine	Apatite	Apatite				
Apatite		Staurolite	Staurolite	⎰Staurolite		Kyanite
Kyanite		Kyanite	Kyanite	⎱Kyanite	Hornblende	Hornblende
	Hornblende*	Hornblende		⎰Hornblende*		Staurolite
			Ferro-magnesian minerals	⎱Garnet		Garnet
	Augite†	Augite		⎱Augite	Augite	
	Olivine	Olivine		⎰Apatite	Olivine	
Monazite				⎱Olivine		

* In the published work given as "amphibole" or "amphiboles."
† „ „ „ „ „ „ "pyroxene."

The spacing is intended to draw attention to the similarities between the series. Minerals occurring in fewer than three of the seven lists have been omitted. In Sindowski's paper the minerals are given not as a continuous series, but as groups shown in the above table by brackets, the minerals in each group are here arranged to show the maximum possible agreement with the other lists.

of occurrence in Recent sediments and (2) its average frequency in non-Recent sediments, the ratio of these two frequencies being taken as a measure for deciding the place of each mineral in the stability series. Since comparison is made in each case with Recent deposits, position in the series may be taken as indicating relative resistance to post-depositional change. This inference involves the assumption that each mineral occurred as frequently in ancient deposits at the time they were laid down as it does in present-day deposits. The close similarity, noted by Pettijohn, between his series and that of Smithson does, however, reassure us that the two lines of reasoning by which these series are obtained are probably sound and that both series relate to the same fundamental property—namely the stability of detrital minerals in subterranean strata. The only important point of disagreement is the position of apatite, but, since many of the workers whose results were used by Pettijohn cleaned and disintegrated their samples with acids which destroy apatite, and since this treatment is more frequently used for old, consolidated

sediments than for recent ones, Pettijohn's calculations would tend to give a lower value for the stability of this mineral.

Pettijohn also drew attention to the complete agreement between his series and that of Goldich (1938), which is based on the study of true weathering.* Goldich's list, however, includes very few heavy minerals, and more extensive research into the mineralogy of soils suggests that resistance to weathering differs in many instances from that indicated by Pettijohn's list. V. T. Allen (1948) has described
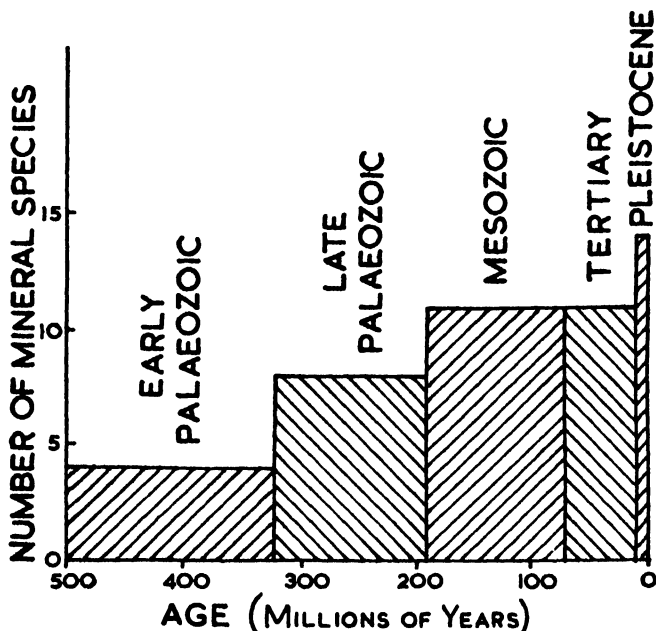
Fig. 3.—Histogram showing variations in richness of heavy mineral assemblages in geological time.

(*After* PETTIJOHN.)

Vertical scale = number of species occurring in *more* than half the examples investigated.

a soil profile in which apatite has proved less stable than hornblende and much less stable than garnet and kyanite. Haseman and Marshall (1945) have reviewed somewhat earlier work carried out by soil workers in U.S.A. Michelson (1943), for example, is stated to have studied soils derived from calcareous glacial drift and to have

* Weathering consists of the breakdown of rocks under mechanical strains caused by weather conditions, and the solution and chemical decomposition of minerals by rainwater in the presence of air (including " soil air "). The term should not be applied to processes which take place beyond the zone in which these agencies are believed to operate.

found apatite persisting under neutral or slightly alkaline conditions, although it had disappeared from acid soils. L. and C. Dryden (1946) from a study of minerals in soils, have built up a stability series which differs from Pettijohn's in having both staurolite and garnet less stable than hornblende.

Sindowski (1949) has published an account of recent work by German sedimentary petrologists and has divided heavy minerals into a series of groups (given in an abbreviated form in Table I) which are stated to show " the resistance of heavy minerals to weathering." The text, however, suggests that this grouping may be an attempt to tabulate a statement of mineral stability which shall be valid both in the zone of weathering and in sedimentary rocks in general. This statement, even when set out in such a way as to make comparison as favourable as possible, differs from that of Pettijohn with respect to garnet and apatite ; and if the fifteen minerals common to both complete lists are set out side by side further discrepancies can be found, particularly in the placing of anatase, epidote and sillimanite. The position accorded to apatite in the Sindowski list might seem to suggest that the series relates to true weathering. It is possible, however, that the German workers may have been influenced by taking a much greater interest in the younger than in the older deposits. The older sediments now available for study are mostly those which have been deeply buried, for otherwise they would not have been preserved from erosion until our own times. In contrast, the Quaternary and Upper Tertiary sediments now accessible consist largely of deposits which have never been deeply buried and the environment to which their minerals have been subjected may not have differed greatly from that which exists in the zone of weathering.

Turning now to the stability of minerals in the face of mechanical disruption we have Freise's mechanical abrasion tests (1931) and Russell's study of the transport of mineral grains by the Mississippi (1937). Freise arrived at a stability series, shown in Table I, which clearly differs from those already discussed. With Pettijohn's *stability* values the *transportwiderstand* values of Freise show little or no correlation. It is, however, interesting to compare the *transportwiderstand* values with the *frequencies* of minerals in recent sediments as arrived at by Pettijohn as a stage in his stability calculations. Graphical study gives some suggestion of correlation, and the minerals whose frequencies are lower than would be estimated from Freise's data are those which are known to be chemically unstable or very local in their occurrence in the crystalline rocks.

It has been a widely held belief that owing to differences in

mechanical properties there is a tendency for some minerals to be destroyed during river transport and others to survive, so that from this cause the composition of sand borne by a river tends to change progressively from source to mouth.   Mackie (1899) reported considerable reductions in the amount of felspars in the course of 30 to 40 miles in some swift Scottish rivers, but these may not be typical of rivers in general, for R. Dana Russell (1937) has shown that for the lower 1000 miles of the River Mississippi there is no evidence of any large *progressive* changes in mineral composition.   Russell found that there were variations in composition, but that these were present even among adjacent samples and were explicable as the effects of local sorting which could be allowed for by dividing each sample into a number of sieve fractions, determining the composition of each and applying an appropriate statistical device.   He satisfied himself that the sediment introduced by the few small tributaries was practically negligible, this stretch of the river being a " natural flume."   His final conclusion was that " the selective destruction of minerals by abrasion and alteration during transport is not only a relatively unimportant process in the lower Mississippi River, but that a large part of the effect of this process is offset by other factors, with the result that sands reaching the Gulf have nearly the same mineral composition as those in the vicinity of Cairo."   The minerals of the amphibole and pyroxene groups averaged between 10 and 20 per cent. of the heavy residue, as determined by grain counting, and Russell particularly noted that they show little or no progressive loss.   He contrasted this fact with the scarcity or absence of these minerals in older sediments apparently derived from the same source rocks, and concluded that decomposition after deposition rather than during transport is the major cause of the disappearance of these minerals.

There is one further line of evidence which lends support to the conclusions reached above.   Geologists have long been familiar with a number of minerals which, if present in a sedimentary rock, can often be described as *authigenic, i.e.* formed in the place where they are now found.   For example, the TiO_2-minerals, anatase and brookite, often occur in large quantities as well-shaped crystals showing no signs of abrasion, and evidently formed *in situ* from some other titaniferous minerals.   This is in keeping with the fact noted by Pettijohn (1941) that anatase has been reported more frequently in the older than in the younger sediments.   Other substances (*e.g.* quartz, the felspars, the clay-minerals) are developed in a similar manner to form new grains, to encrust older grains or to fill interstices, and their development contributes to the process whereby

unconsolidated sediments are gradually converted into hard rock. Waldschmidt (1941) and Gilbert (1949) have attempted to learn the sequence in which such changes take place by studying thin sections of sandstones in Western U.S.A., but much more work needs to be done before the process is thoroughly understood.

The processes outlined above—the destruction of minerals in sedimentary rocks and the consequent formation of new minerals—are of a less drastic nature than those to which geologists have given the name *metamorphic*, and it is customary to class them under the term *diagenesis*. It is generally recognised that many types of diagenetic change are associated with deep burial and many writers have stated or implied that pressure plays an important part. In the Yorkshire Jurassic rocks (Smithson, 1939, 1941, 1942) variations in the intensity of diagenesis are closely related to variations in the thickness of the beds and to the major axis of folding in the region. There are not many regions in which lateral changes in the beds are so easily mapped—the dips of the rocks are extremely low and the region is deeply dissected by valleys so that beds of the same age can be sampled over a wide area—but in the coalfields, as a result of mining operations, it is practicable to trace variations in the constitution of the individual beds over considerable areas. Although in these regions attention has been devoted almost exclusively to the coal seams, the results appear to have some bearing on the present problem. Like the changes discussed above, the devolatilisation of a coal seam is a change due to conditions less severe than those which give rise to metamorphism. In South Wales the volatile-content of the coal in each locality decreases with depth, but still greater variations are found as each seam is traced towards the north-west margin of the field. Although earlier opinion favoured the view that pressure due to *depth of burial* was the chief cause of change, Trotter (1949) has correlated the major variations in devolatilisation with differences in distance from the major thrust plane of the area. It would be of interest if the heavy mineral suites of this area could be mapped to discover whether their variation corresponded in any way to the distribution of coal volatiles, and particularly whether the conditions which have affected the coal have caused any progressive impoverishment of the heavy mineral suites of the sandstones.

Sufficient evidence has now been set out to affirm that the mineral assemblage found in a sediment of any age will differ from that which was present when the sediment was laid down and that the amount of difference will depend upon time and upon environment. Minerals which, in a crystalline rock, remain apparently unaltered

for hundreds of millions of years may survive for much shorter periods when transferred to an arenaceous rock. The earliest changes are qualitative (*e.g.* changes in the form of the grains), the later ones quantitative (*e.g.* reduction in the number of grains of some species and a consequent increase in the percentage of the surviving species). These ideas are undoubtedly disturbing to the geologist or pedologist wishing to know the source rocks of a particular deposit or the parent material or parent rock of a soil, for it is certain that some mistakes have been made through regarding the composition of a mineral assemblage as a fixed characteristic of a sedimentary deposit. It is probable that the errors are in some cases negligible, in others serious, but it is not yet clear how they are to be estimated and rectified. If it had been possible to arrange minerals in a stability series valid for all the environments involved the problem would have been simpler, but a comprehensive stability series can never be more than a rough generalisation.

There appear to be two promising ways out of these difficulties. Firstly, we can follow up work which has been done upon varietal characteristics (form, colour, etc.). Brammall (1928), for example, has shown that in the granite and associated rocks of Dartmoor, many of the accessory minerals possess distinctive varietal features, a fact successfully utilised by Groves (1931) in investigating the contribution made by the Dartmoor rocks to the sediments of the south of England. Secondly, we can give attention to the quantitative aspects of the most stable species. Mineralogical and chemical estimations of zircon in the successive layers of a soil profile may be made the starting point for studying the changes in the less stable constituents (Haseman and Marshall, 1945). Variations in the sizes of zircon grains throughout the lateral extent of a particular bed or formation may give evidence as to the direction of transport of the detritus (Smithson, 1942 ; P. Allen, 1949).

In such work, P. Allen (1944) has rightly stressed the importance of applying the standard methods of statistics. Indeed, the quantitative approach which has characterised most aspects of petrological research in recent years makes it inevitable that statistical criticism should be brought to bear on the data collected. A. L. Dryden (1931) and P. Allen and Miss Walder (1945), for example, have pointed out that sedimentary petrographers often count only a few hundred grains of a mineral assemblage and then express the composition with a degree of accuracy not justified on statistical grounds. It is possible, however, that if the work of counting has been undertaken in the belief that the percentage composition has remained constant with the passage of time, the application of statistical

methods is not an adequate safeguard, since it may appear to give a qualified blessing to data which for the purpose in mind should be condemned on geological grounds.

Research involving numerical estimates of mineral assemblages continues, sometimes with and sometimes without rigorous statistical treatment. In Europe, the workers who follow Edelman (1938) are satisfied that, by roughly estimating percentage composition and inspecting the accumulated data, the assemblages can be classified into types characteristic of " distributive provinces," the mapping of which discloses the palæogeography of the period of deposition. Smithson's work on the Jurassic rocks of Yorkshire employing similar methods led, as we have seen, to the conclusion that not a *distributive* province but one of *mineralogical change* was the only unmistakable feature present. " I have had the impression for many years," wrote Boswell (1942), " that the Jurassic system in Yorkshire includes mineralogically ' abnormal ' formations." Perhaps, therefore, it is only in exceptional cases that grain-counting completely fails to give valid palæogeographical information. Yet in how many cases are we dealing with the perfectly " normal " or ideal sediment for which distributive provinces can be correctly established, and how often with sediments of an intermediate type for which distributive provinces can be established only with partial success ?

We have touched only upon such recent research as could be linked up with a central theme, but if we try to sum up what the sedimentary petrologist has chiefly gained (or should have gained) from all the research of the last fifteen years we should say that he has suffered a healthy clarification of his ideas, which should lead to greater caution in the interpretation of the data and to the realisation that work still remains to be done on many problems formerly thought to have an obvious solution.

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METEOR IONISATION IN THE UPPER ATMOSPHERE

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1. Introduction

METEORS are minute pieces of stone and iron which produce the familiar spectacle of " shooting stars " when they enter the earth's atmosphere at very great speed. Most of the meteoric debris which the earth encounters in its journey through space is finally disintegrated by impact with the air molecules at altitudes between 80 and 120 km. Although the major part of the energy of the meteor is spent in producing light and heat, the small fraction spent on ionisation produces dense electron concentrations which scatter sufficient energy to be observed (as short-lived echoes) on modern radio apparatus. This survey is concerned firstly with the total ionisation produced in the atmosphere by the meteoric debris, and then with the intense local ionisation produced by individual meteors and the behaviour of the electrons during and after the disintegration of the meteor. The fundamental meteoric phenomena are summarised, but the significant contributions made to the subject of meteor astronomy through the ability to observe the primary phenomena under all conditions of light and cloud are not specifically included.

The detailed history of the subject has been given recently elsewhere [1]. This paper is more concerned with the present state of our knowledge and with the many complex problems still-awaiting solution.

2. The Fundamental Meteoric Phenomena

Although there is much dispute about the origin of the meteoric matter, certain fundamental phenomena are well known. The most important is the occurrence at certain times of the year of meteor " showers." These arise when the earth sweeps through an accumulation of debris which is itself moving in a definite orbit under the

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gravitational force of the sun. The effect is illustrated in Fig. 1, in which the debris is moving in the orbit pqr. Assuming for the moment that the debris is uniformly distributed around this orbit, then when the earth crosses the meteoric orbit at q a large concentration of debris will enter the earth's atmosphere and will continue to do so until the earth emerges from the stream. The meteors in this stream will approach the earth from the same apparent direction in space. This direction is known as the *radiant* of the stream, and meteor showers are usually named after the star or con-stellation near which the radiant appears to lie.
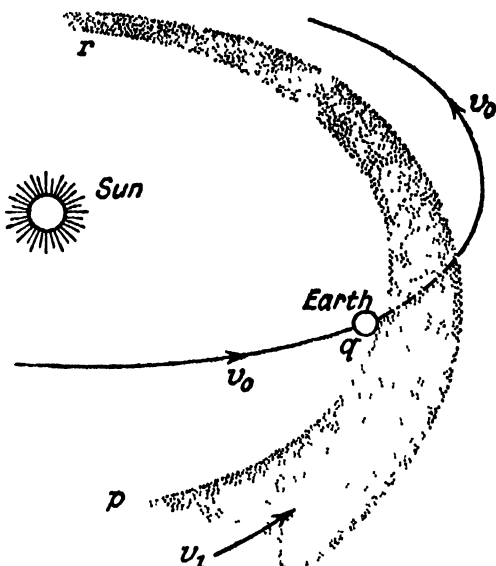
Fig. 1.—Production of a meteor shower.

Until the advent of the radio echo technique (which enables daytime showers to be observed [2]), about twelve such showers of regular occurrence were known. The ability to observe in the daytime by the radio method has led to the discovery of a further dozen major streams during the summer months [2, 3].

The extent of the debris associated with specific orbits varies greatly. Thus the great Giacobinid shower of October 1946 was of exceptional intensity, but lasted only for 6 hours, and hence the stream, although of great density, could not have been more than some 400,000 miles in cross-section. At the other extreme the regularly occurring Perseid shower of August is much less active but lasts for 21 days, so that the debris must extend for something like 50 million miles in space.*

The velocity with which the meteoric matter enters the atmosphere depends on the position and eccentricity of the orbit of the stream. In Fig. 1 v_0 is the earth's orbital velocity (30 km./sec.) and v_1 the velocity of the meteoric debris about the sun. The

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* Estimated from the distance which the earth moves in this time. Actually the earth moves obliquely through these orbits and hence their actual cross-section is somewhat less.

limiting value for v_1 if the debris is moving in an elliptical orbit is 42 km./sec. Hence the velocity of meteors in the atmosphere can vary between limits of 12 to 72 km./sec. The existence of hyperbolic meteor orbits, which implies that the meteor comes from outside the solar system, is in great dispute.

The origin of these meteoric streams is not known. There are some half-dozen cases in which it appears certain that the debris is associated with a comet or is the remains of a disintegrated comet. The Giacobinid shower referred to above has so far only occurred when the earth crosses the orbit of the Giacobini-Zinner comet fairly close to the comet itself. Thus in 1946 when the earth passed through the orbit 15 days behind the comet there was a very great shower, but in the three subsequent years when the earth has crossed the orbit at a much greater distance from the comet there has been no shower whatsoever. The Giacobini-Zinner comet is of recent origin. On the other hand, the Perseid shower is believed to be the remains of a comet of great antiquity. In this case the debris has probably been spread out by perturbation over thousands of years and is now fairly uniformly distributed around the orbit so that the shower is very regular. Many of the showers, however, have no known parent comets and there are many comets whose orbits are crossed by the earth's which do not yield meteor showers.

Apart from these isolated showers, there are large numbers of sporadic meteors which do not appear to be grouped in any marked orbits or streams. These may have arisen by perturbation of debris which was originally localised in orbits, or some may be of interstellar origin—a vital problem which still remains to be settled.

3. The Quantity of Meteoric Matter intercepted by the Earth

On a clear, moonless night the unaided eye can see about 10 sporadic meteors per hour on the average. The actual number shows marked diurnal and seasonal variation, being greatest at 06^h, when the observer is on the forward side of the earth, and at the autumnal equinox, when the apex of the earth's way is at its greatest elevation. During times of meteor showers these numbers may be greatly augmented. Showers such as the Perseids and Geminids give 40 to 60 per hour for several nights, while the remarkable Giacobinid shower in October 1946 is believed to have produced nearly 10,000 per hour for a short time near maximum.

The actual numbers of particles entering the earth's atmosphere is very much greater, since the limit of visibility is about 5th magnitude. According to Fletcher-Watson [4], the total mass of meteoric

matter entering the whole of the earth's atmosphere is 11 kg. per stellar magnitude per day.   If we assume that meteors of less than 30th magnitude are blown away by the sun's radiation pressure and that meteors of magnitude greater than − 10 fall to the earth as meteorites, then we find that 450 kg. of meteoric matter is incident on the earth's atmosphere per day.   Taking the area of the atmosphere as 5×10^8 km.² the mass of meteoric material coming into the atmosphere is $\sim 10^{-8}$ gm./km.²/sec.

These quantities will be enhanced during the occurrence of showers.   A small shower giving a visual rate of 10 per hour will contribute an additional 10^{-8} gm./km.²/sec.   Major showers like the Perseids and Geminids will contribute about 5×10^{-7} gm./km²/sec.   The 1946 Giacobinid shower must have produced some 10^{-5} gm./km.²/sec. in the atmosphere.

The above figures assume that the number distribution amongst different magnitudes in both the sporadic and shower meteors is such that the same mass exists in each magnitude from − 10 to + 30. This has been verified only over limited ranges of magnitude [4]. In particular, it seems likely that some of the very old streams may only contain the larger particles, since the smaller debris may have been dispersed over a long period of time.   Nevertheless, the figures provide the best guide at present available as regards the quantities involved.

The total energy brought into the atmosphere by the meteoric debris can be estimated by assuming an average velocity of 40 km./sec. This gives an energy flow of some 4×10^{13} ergs/sec., rising during active showers to $\sim 10^{15}$ ergs/sec. and to $10^{16} - 10^{17}$ ergs/sec. during very intense showers like the Giacobinids.   It is interesting to note that these quantities are of the same order of magnitude as the energy brought into the atmosphere by cosmic rays ($\sim 3 \times 10^{16}$ ergs/sec.).

4. The Process of Ionisation

A discussion of the various theories of meteor ionisation has been given by Herlofson [5].   Present-day theories are based mainly on the work of Öpik [6].   The radii of even the very bright meteors are a fraction of a millimetre, which is much smaller than the mean free path of the atmospheric molecules at altitudes where the meteor evaporates.   The surface of the meteor will therefore be subjected to bombardment by single air molecules, a large proportion of which will be trapped in the meteor and give up their kinetic energy as heat.   Eventually the heat supplied to the meteor in this manner will cause it to evaporate and the meteor atoms will escape with thermal velocities relative to the meteor.

Since the binding energy of the atoms in the meteor is only a few electron volts, the energy given up by each trapped air molecule will be sufficient to evaporate a large number of meteor atoms. Hence the total air mass intercepted before complete evaporation takes place is small compared with the meteor mass, and the meteor will not be retarded. The atmosphere does not tend to stop the flight of the meteoric body, but rather to break it up into single atoms which immediately disperse in the surrounding air.

The shapes of the theoretical light and ionisation curves based on the above mechanism have been calculated by Öpik [6] and Herlofson [5] and are in good agreement with the observed phenomena. Of particular interest to the present discussion is the calculation of the magnitude of the ionisation produced by a meteor of given size and velocity. The velocities of the evaporated atoms relative to the atmosphere are of the order of 40 km./sec. and their kinetic energies are some 100 to 1000 eV. In subsequent collisions with the air molecules they will produce heat, light and ionisation. Unfortunately the knowledge at present available regarding the probabilities for transitions to the various levels in the colliding atoms is very limited. It is known, however, that the probabilities for excitation and ionisation in the collision of two heavy particles are very much smaller than for the collision between an atom and electron of comparable energy [7]. Thus it is to be anticipated that most of the kinetic energy of the meteor will be converted into heat, and relatively little into light and ionisation. The calculations made by Öpik on the basis of data at present available indicate that the kinetic energy of the meteor will be divided in the ratio 10^4 (heat) : 10^2 (light) : 1 (ionisation).

On the basis of these views Herlofson [5] gives the following data calculated for a very faint and very bright meteor moving with a velocity of 40 km./sec.

Magnitude	+ 1	+ 6
Radius	0·08 cm.	0·02 cm.
No. electrons/cm. path	10^{13}	10^{10}
Height corresponding to maximum of light and ionisation	85 km.	95 km

5. The Total Ionisation Produced by Meteors in the Atmosphere

Recent experimental measurements of ionisation in the trails of visually observed meteors (see § 9) indicate that the theory outlined above predicts ion densities of the correct order of magnitude. It is therefore possible to obtain figures for the total ionisation created

in the atmosphere by meteoric impact. The experiments of Sutton and Mouzon [7] indicate that the probability of a meteor atom producing a free electron is 10^{-2}. Thus the number of electrons produced by m grams of meteoric matter of atomic weight A will be given by

$$n = \frac{No}{A} m \times 10^{-2}$$

where No is Avogadro's Number. If we assume that the meteoric matter is iron, then the number of electrons produced per gram will be

$$n = 1 \cdot 1 \times 10^{20}$$

It is instructive to compare the rate of ion production with the general level of E region ionisation, for which we require the actual volume density. There are two cases to consider:

(a) *Sporadic Meteors.*—The sporadic meteors will have a velocity distribution from 12 to 72 km./sec. (assuming that there are no interstellar meteors) and will ionise over a height range from about 80 to 120 km. According to the estimates made in § 3, the mass of sporadic material incident on the atmosphere is $\sim 10^{-8}$ gm./km.²/ sec.; hence the volume density of ionisation produced will be $3 \cdot 0 \times 10^{-5}$ electrons/c.c./sec.

(b) *Shower Meteors.*—The shower meteors form homogeneous velocity groups and the ionisation due to the particles in a given shower will be confined to a narrower depth of atmosphere, say 10 km. A shower with the same visual rate as assumed for the sporadic meteors (10 per hour) will thus produce $1 \cdot 2 \times 10^{-4}$ electrons/c.c./sec. The maximum contributions occur in the summer daytime when two or more radiants may be active simultaneously with a combined rate of up to 200 per hour [8]. The rate of electron production is then $2 \cdot 4 \times 10^{-3}$ electrons/c.c./sec.

The Giacobinid shower of October 10, 1946, represents an unique event in which the echo rate reached nearly 10,000/hour for a short period around maximum [9]. This represents a production of electrons of $1 \cdot 2 \times 10^{-1}$/c.c./sec.

The average E region ionisation during a midsummer day is approximately $1 \cdot 5 \times 10^5$ electrons/c.c., falling to $1 \cdot 0 \times 10^4$ electrons/c.c. at night. Taking the recombination coefficient as 10^{-8}/sec., this implies a rate of ion production ($N^2\alpha$) of approximately 225/c.c./sec. during the midsummer day and 1/c.c./sec. during the night. Thus the ion production due to meteors—ranging from 3×10^{-5}/c.c./sec. to $2 \cdot 4 \times 10^{-3}$/c.c./sec. during the summer daytime, at all times represents a negligible contribution to the E region ionisation. For a short period during the exceptional Giaco-

binid shower of October 10, 1946, however, the rate of ion production became nearly sufficient to maintain the normal night time E region ionisation.

These conclusions are in disagreement with the earlier estimates of Skellett [10] and Pierce [11] who, assuming that almost the entire kinetic energy of the meteor was spent in ionisation, concluded that the ionisation due to meteors made a prominent contribution to the normal level of ionisation in the E region.

6. THE LOCAL INTENSE COLUMNS OF IONISATION PRODUCED BY METEORS

Although the total amount of ionisation produced is negligible compared with the normal level of E region ionisation, the initial concentrations of electrons produced as the meteor evaporates are very great, and give rise to effects of great consequence in the study of the astronomy of meteors and the physical processes taking place in the high atmosphere. The primary process, as the meteor evaporates, is the production of a long narrow column of ionisation some 10 km. long at altitudes of 80 to 120 km., depending on the velocity of the meteor. The line density of electrons in this column is some 10^{10} to 10^{12} electrons/cm. for meteors in the visual range. The initial radius of the column will be comparable with the mean free path, which is of the order of 10 cm. at 100 km., and hence the initial volume densities will be in the region 10^8 to 10^{10} electrons/c.c. These densities will decrease rapidly under the influence of diffusion and recombination.

The scattering of radio waves from these transient concentrations of electrons can be readily observed with conventional radar apparatus working on frequencies above the critical frequencies for the E and F regions. The majority of the echoes are short-lived, although occasionally echoes are observed lasting for a minute or more on the lower frequencies. The conventional methods of observation are

PLATE I

FIG. 2.—Appearance of a radio echo from a meteor trail on a range-amplitude cathode ray tube display. (Range horizontal, amplitude vertical.) The echo which is at a range of 470 km. is from a Perseid meteor on 1947 August 4.

FIG. 3.—Appearance of radio echoes from meteor trails on an intensity modulated cathode ray tube display. (Range vertical, time horizontal.) An unusually long duration echo (1 minute) is visible with three transient echoes appearing as white spots. The record was obtained during the daytime showers on 1948 June 17.

FIG. 6.—A good example of radio wave reflection from the ionisation near the head of a moving meteor. This is a rare example in which both the approach and regression of the meteor can be observed.

PLATE I
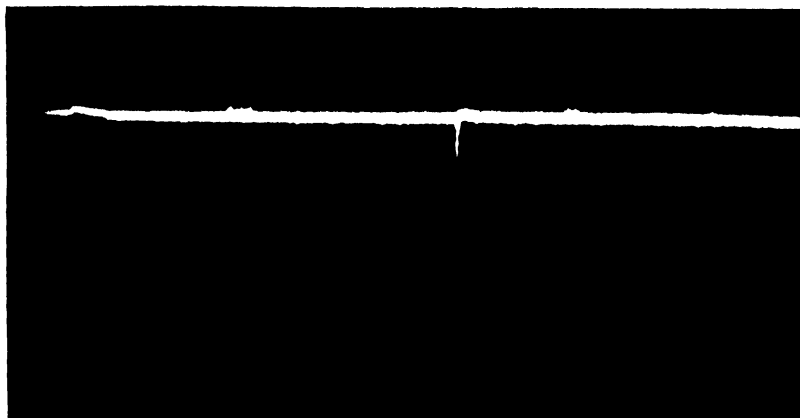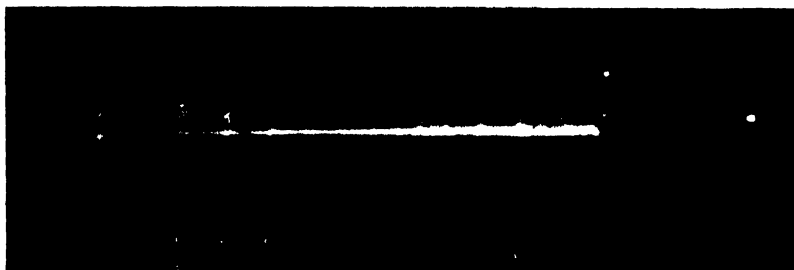
Fig. 2.

Fig. 3.

Fig. 6.

PLATE II

FIG. 8.   ◄   – Time

FIG. 9.   Time ⟶

FIG. 11.   ◄── Time

FIG. 12.   ◄──── Time
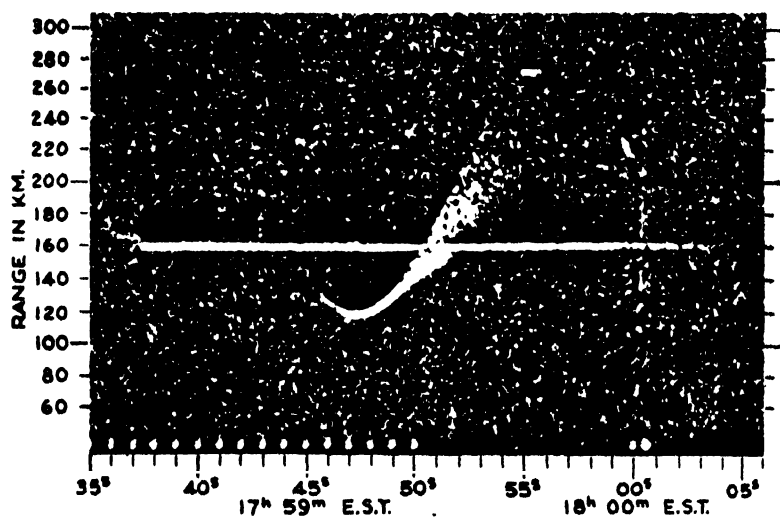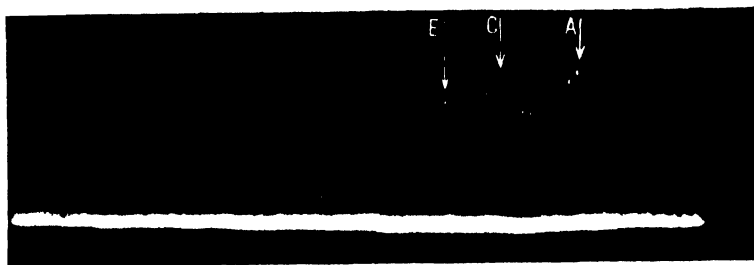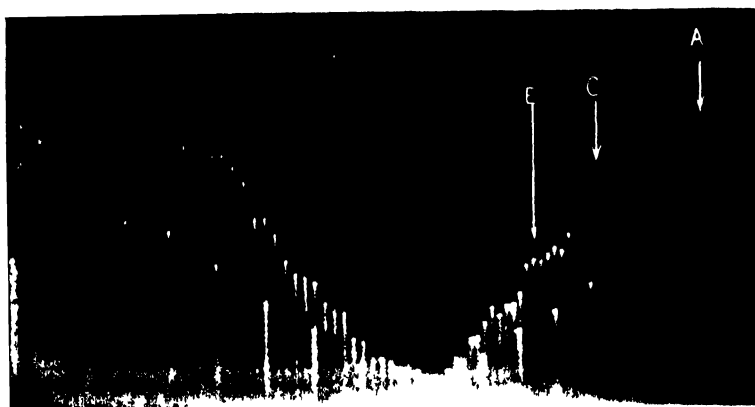
either the range-amplitude display, in which the range and ampli-
tude can be measured (Fig. 2, Plate 1), or the intensity modulated
display (Fig. 3, Plate I), in which the duration and range can be
measured. Some of the techniques and results will be discussed
in the following sections.

7. The Number of Transient Echoes Observed

Early workers on the ionosphere using radio frequencies in the
region of 20 Mc./s. observed large numbers of transient echoes which
had a diurnal and seasonal variation. As a result of experience
during the 1932 Polar Year Expedition, Appleton [12] suggested
meteors as a possible cause of these echoes, and in America Skellett
[13] associated some of the larger bursts with visible meteors pass-
ing overhead. There did not seem to be any correlation between the
numbers of echoes and the meteoric phenomena which were visible to
the eye ; and the precise origin of the echoes remained in doubt.

Using Army radar equipment on a much higher frequency
(70 Mc./s.) in 1945 Hey and Stewart [14, 15] made some important
observations which led to a considerable clarification of the subject.
On this higher frequency the echoes are less frequent and a definite
correlation was observed between increases in echo rate and the
occurrence of well-known major meteor showers. Fig. 4 shows the
echo rates observed by Hey and Stewart. The peak in January

PLATE II

FIG. 8.—The diffraction of 72 Mc./s. radio waves from a meteor trail during forma-
tion. The Fresnel zones (maximum A, C, E, cf. Fig. 7) are clearly visible.
The time interval between successive pulses is 1·3 milliseconds. The range
of the echo (445 km.) was photographed on another display and the velocity
can be calculated from the zone spacings. The meteor occurred during
the daytime streams on 1949 May 14^{d}07^{h}09^m U.T. and had a velocity of
59·4 ± 2·1 km./sec.

FIG. 9. The continuous wave counterpart of Fig. 8. By using a C.W. transmitter
on 30 Mc./s., McKinley and Millman have been able to photograph the amplitude
changes continuously as the meteor trail moves through the aerial beam. The
effect can be made audible, if the reflected wave is made to beat with the direct
ground wave, as a doppler whistle. The Fresnel oscillations are visible before
the perpendicular point, since the ground wave provides a reference phase.
Photographed on 1948 Dec. 11^{d}03^{h}14^m, the velocity of the meteor was
35·0 km./sec.

(By kind permission of DR. D. W. R. McKINLEY.)

FIG. 11.—The beginning of an abnormal type of long duration echo observed on
72 Mc./s. The Fresnel zones (A, C, E, cf. Figs. 7 and 8) are followed by a
big surge in amplitude, which has not occurred in the normal type shown in
Fig. 8. From a meteor trail at a range of 385 km. on 1949 June 11^{d}10^{h}29^m U.T.
The time interval between successive pulses is 1·3 milliseconds and the velocity
of the meteor 43·1 ± 2·1 km./sec.

FIG. 12.—An example of the high-speed amplitude fluctuations in the radio echo
from a meteor trail observed on 72 Mc./s. The beginning of this type of
fluctuation is seen in Fig. 11. The time interval between successive pulses is
1·3 milliseconds. The meteor was a Perseid occurring at a range of 525 km.
on 1949 August 9^{d}07^{h}37^m U.T.

corresponds to the intense short-lived Quadrantid shower. Similar peaks were observed in April and May corresponding to the Lyrids and η-Aquarids respectively. These all agree closely in time with the known visual occurrence of these showers. Convincing evidence that, at least on these frequencies, all the short-lived echoes are associated with meteors was provided by the Giacobinid shower of October 10, 1946. For example, in the apparatus used by Lovell, Banwell and Clegg [9] on 72 Mc./s. the normal echo rate with no showers active was 2 per hour. This condition applied until 00^h U.T. on October 10, when the echo rate suddenly increased, until by 03^h 40^m U.T. the rate rose to the enormous peak of *168 per minute*. By 06^h00 U.T. the rate had decreased to its normal " no shower " rate of 2 per hour. These times corresponded precisely with the calculated time of passage of the earth through the orbit of the Giacobini-Zinner comet.
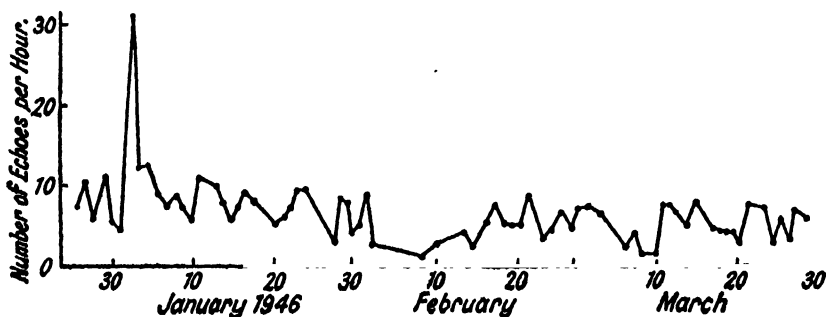
FIG. 4.—The rate of occurrence of transient echoes observed by Hey and Stewart in 1946, showing the sharp peak at the time of the Quadrantid shower.

(From *Proc. Phys. Soc.*, **59**, 858, 1947.)

On the frequencies in the 70 Mc./s. region a major proportion of the reflections are critically aspect sensitive, and the radio echo from a given trail can only be observed if the foot of the perpendicular from the observing station to the trail lies in the aerial beam. This property of the reflections was suggested by Pierce [11] in 1938 and proved in the work of Hey and Stewart [15]. At the peak of the Giacobinid shower the directional aerial used by Lovell, Banwell and Clegg [9] was redirected so that the beam was pointing in the direction of the radiant point. The echo rate fell to 4 per cent. of its previous value, but rose again to the exceptionally high value as soon as the beam was returned so as to be perpendicular to the radiant.

If the frequency of the radio apparatus is reduced, while its equivalent sensitivity is maintained at a constant value, the transient

echo rate increases. Thus Fig. 5 shows a simultaneous 24-hour record on frequencies of 36 and 72 Mc./s. On the 72 Mc./s. apparatus it is known from experience that a close relation exists between the observed echo rate and the rate of visual meteors. All the echoes observed on 72 Mc./s. were also observed simultaneously on 36 Mc./s., but in addition there was an extremely high background rate with a diurnal variation on this lower frequency. This type of variation, which exists independently of the presence of major meteor showers, caused the earlier uncertainty in the interpretation of the transient echoes. The recent work of Millman and McKinley [16] on these low frequencies has indicated the correct interpretation
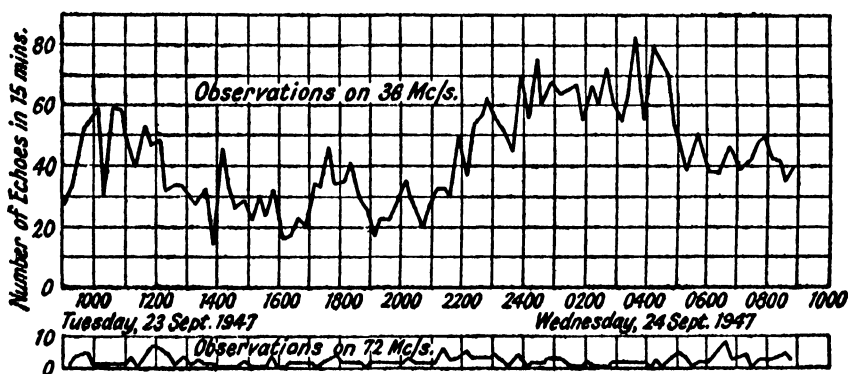
FIG. 5.—Hourly rates of transient echoes observed on 36 Mc./s. and 72 Mc./s. equipment during a simultaneous 24-hour watch Sept. 23–24, 1947.

of these phenomena. By an extensive combined programme of radio and visual observation these workers have shown that the aspect sensitivity reflections are not unique on these lower frequencies. Although a trail passing through the aerial beam at right angles to the station gives the strongest echo, the reflection from a trail passing at an angle through the beam can still be seen. Their work also indicates that a single trail can apparently change rapidly from its initial columnar formation to give localised concentrations of electrons, and hence a multiplicity of echoes results, whereas on the higher frequencies only the original columnar reflection is observed.

8. THE MECHANISM OF SCATTERING

At the instant of formation of the meteor trail the electrons are contained in a long column whose diameter is small compared with the radio wavelengths used. A simple calculation of the intensity of the scattered radio wave from such an assembly can be made if

the density of electrons is insufficient to modify the incident radio wave. In this case the electrons across the column will scatter in phase and the number N, scattering coherently, will be those contained in a column of length equal to the first Fresnel zone

$$N = \alpha \sqrt{\frac{\lambda R}{2}}$$

where R is the range, and α the number of electrons formed per centimetre path by the meteor.

By introducing the parameters of the radio apparatus it can be shown (Lovell and Clegg [17]) that

$$\alpha = \sqrt{24\pi} \left(\frac{mc^2}{e^2}\right) \frac{1}{G} \sqrt{\frac{\varepsilon R^3}{P\lambda^3}} \qquad . \qquad . \qquad . \quad (1)$$

where G is the power gain of the receiving and transmitting aerials over a half wave dipole, ε is the scattered power delivered to the receiver, P is the peak transmitter power and (mc^2/e^2) the inverse of the classical electron radius.

This relationship is capable of experimental verification, since ε and R can be measured for a given meteor trail and G, P and λ are known constants of a given apparatus. Lovell and Clegg [17] made simultaneous observation of radio echoes from the same meteor trail on different wavelengths and found that the predicted relation between ε and λ was obtained over the range of wavelengths used (1·4 m. to 8 m.).

The above theory also predicts correctly the variation in number of echoes recorded as λ changes over the range 1·4 m. to 6 m. It does not account, however, for the sudden increase in rate found on longer wavelengths, and evidently, from the observations of Millman and McKinley [16], other scattering processes can also take place on these longer wavelengths.

Herlofson [18] has pointed out that the scattering formula (1) may not always apply, even on frequencies as high as 70 Mc./s., since, if the present estimates of line densities are correct, some of the brighter meteors will produce concentrations in excess of the critical densities for these frequencies. He has considered the fundamental theory for the case of a radio wave returned from an electron column where the density is sufficient in the core to give zero or negative dielectric constant. In this case plasma oscillations will be excited in the column if the incident waves are polarised *along* the ionisation gradient, but not if they are polarised normal to the gradient. For the former case the scattering formula given above must be considerably modified, and a rigorous analysis shows that

the intensity of the reflected wave may be considerably enhanced. Thus, when conditions of negative dielectric constant apply, the scattered wave will be returned with greater strength if the electric vector is normal to the electron trail.

According to the data given in § 4 and § 9, a meteor on the limit of visibility produces about 10^{10} electrons/cm. path and at the instant of formation the size of the column will be comparable with the mean free path—say 20 cm. diameter. Thus the *volume* density in the trail will be of the order of $2 \cdot 5 \times 10^7$ electrons/c.c. Now the *critical* electron density for refraction of the radio waves varies from $6 \cdot 1 \times 10^7$ electrons/c.c. for radio frequencies of 70 Mc./s. to $1 \cdot 1 \times 10^7$ electrons/c.c. for frequencies of 30 Mc./s. Hence, as the radio frequency is decreased, increasing numbers of meteor trails will possess electron densities above the critical value and the echo rate will rise sharply. The effect is augmented because for each decrease in visual magnitude $2 \cdot 5$ times as many meteors are incident on the atmosphere.

9. MEASUREMENT OF INITIAL ELECTRON DENSITIES IN THE METEOR TRAIL

The direct measurements of electron density in meteor trails have so far been made by using formula (1) and assuming that the simple scattering theory is correct. By carrying out a combined visual and radio echo watch it is possible to measure the amplitude of the radio echo produced by a visible meteor. This yields ε and, since R is also measured and G, P and λ are known, α can be calculated. The combined experiment has been carried out during the 1946 and 1947 Perseid shower [19] and during the 1946 Giacobinid shower [9]. The three sets of results are in good agreement and yield values for α between 10^9 and 10^{12} electrons/cm. path. Although no precise correlations with visual magnitude have yet been made, the results indicate that a meteor near the limit of naked eye visibility produces about 10^{10} electrons/cm. path. This result is in good agreement with the theoretical values referred to in § 4.

The above experiments were made on a frequency of 72 Mc./s., at which it is believed that only the very bright meteors produce electron densities above the critical value and where the use of the simple formula is justified. Experiments are now in progress to test this assumption, as a result of which it should be possible to make more exact estimates of the line and volume density of electrons produced by meteors of given magnitude.

10. OBSERVATION OF THE ELECTRON TRAIL DURING THE PROCESS OF FORMATION

The electron columns of meteors are created at speeds of 20 km./sec. to 70 km./sec., and possibly higher for some of the infra visual meteors. The normal radio echo observed by eye on a conventional display, therefore, represents scattering from a completely formed trail. In order to measure the speed of the meteor and to study the physical processes occurring as the meteor moves through the atmosphere, it is necessary to observe this process of formation. Three techniques have been devised which enable this to be done.

(a) *Observation of Scattering from the Head of the Meteor Column.*—During the 1946 Giacobinid shower, Hey, Parsons and Stewart [20] made a continuous record of the activity by displaying the received echoes as intensity modulation of a linear range trace. This was photographed on a film moving at right angles to the trace with a speed of 2·4 mm./sec. Several of these records showed a faint, fast-moving echo prior to the formation of the main echo. This was attributed to energy scattered from the ionisation at the head of the approaching meteor, the main intense echoes being observed when the meteor trail crosses the point of intersection of the normal from the observing station to the trail. The explanation of this moving head echo appears to be that the density of ionisation exceeds the critical value for the frequency employed. On frequencies of 60–70 Mc./s. these are very rarely observed and must originate from meteors of exceptional brightness. It is to be expected that the phenomenon would become more frequent as the radio frequency is decreased. This is found to be the case and a large number of such observations have since been made by Millman and McKinley [16, 21, 22] using a frequency of 30 Mc./s. A reproduction of one of these records is shown in Fig. 6, Plate I. Since the record enables range to be measured against time, it is possible to determine the velocity of the meteor.

(b) *Observation of the Diffraction of Radio Waves from the Trail during Formation.*—It was first suggested by Herlofson [5] that it should be possible to observe the radio wave analogue of the Fresnel diffraction pattern as the column of ionisation is formed across the aerial beam. As successive zones are formed when the meteor sweeps through the aerial beam the expected amplitude variations are as shown in Fig. 7. The practical observation of this phenomenon is difficult technically for the following reasons. If we consider a typical meteor observed at a range of 300 km. on a

radio apparatus working on a wavelength of 4 m., the length of the first Fresnel zone ($\sqrt{\lambda R/2}$) will be of the order of 800 m. The meteor is moving at a speed of, say, 40 km./sec. and hence will move through this zone in 0·04 second. The spacing and times for zones of higher order will be even less, and thus any technique for observing the phenomenon must be capable of yielding information about the amplitude of the scattered radio wave in periods of less than 0·04 second. In order to look for this diffraction phenomenon, Ellyett and Davies [23, 24] developed an apparatus in which the amplitude of successive radio pulses, scattered from the meteor trail, could be
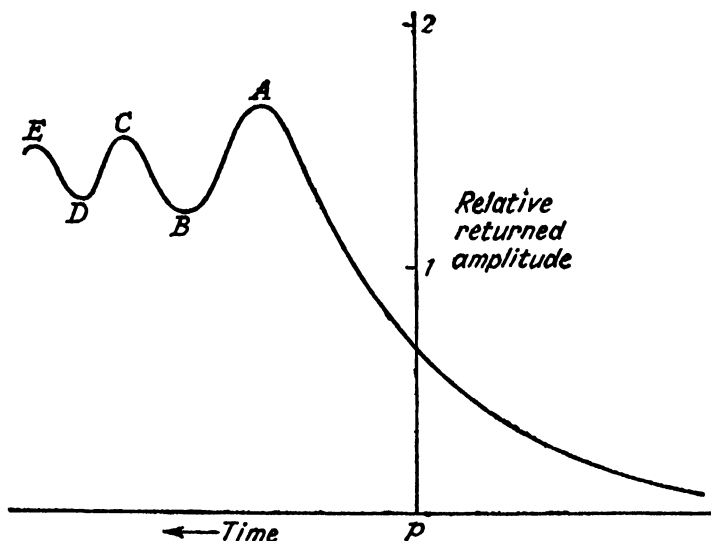
FIG. 7.—Variation in amplitude to be expected due to diffraction of radio waves from a meteor trail as it is formed across the foot of the perpendicular (P) from the observer to the trail. The zone maxima and minima (ABCDE) may be compared with the actual photograph shown in Fig. 8.

photographed. If the pulse recurrence rate of the transmitter is 600 cycles per sec., for example, there will be 24 pulses during the time in which the meteor is traversing the first Fresnel zone for the case discussed above. It is necessary for the apparatus to be initiated automatically by the first scattered pulse returned from the meteor trail as it enters the first zone just before the normal reflecting-point. Since this is of small amplitude, the apparatus must also be able to discriminate against noise impulses in favour of a true meteor echo.

By using this technique Ellyett and Davies found the expected Fresnel type fluctuations in a number of meteor records obtained with the automatic apparatus. A sample of the echo pattern is

shown in Fig. 8, Plate II. By selecting a group of meteors moving with the same velocity and by measuring the Fresnel zone separation for meteors recorded at different ranges, it was possible to show that the analogy with optical diffraction theory holds precisely. The technique is directly applicable to the measurement of velocities, since the width of the zones can be calculated from the measured range, and the time from zone maxima to minima is measured accurately.

A variation in this technique has recently been used by Manning, Villard and Peterson [25] and by McKinley [26]. These workers use the radio pulse technique for measurement of range only, and observe the variations in amplitude given by a continuous radio wave reflected from the meteor trail beating with the direct ground wave from C.W. transmitter to receiver. A sample record obtained by McKinley is illustrated in Fig. 9, Plate II.

(c) *Observation of the Doppler Effect.*—In 1941 Chamanlal and Venkataraman [27] heard weak whistles of an unusual character when they tuned to the unmodulated carrier (7 Mc./s.) at 10 miles from the Delhi radio transmitter. By visual correlation these workers showed that the whistles were associated with meteors. Until recently it has been assumed that such whistles are due to the radio wave reflection from the head of an approaching meteor, providing the C.W. and audible equivalent of the moving echo phenomenon dealt with in (a) above. The theory has been given by Appleton and Naismith [28], and also by Manning [29] who has used the method for measuring the velocity of approach of the meteor.

McKinley [26], however, has now given convincing arguments to show that the majority of the so-called "doppler whistles" are due to the intensity and frequency changes during the Fresnel zone formation and are, in fact, the audible and C.W. counterpart of the diffraction phenomenon discussed in (b) above. The doppler whistle due to reflection from the moving patch of ionisation in the vicinity of the meteor head is a much rarer phenomenon and is confined to the very intensely ionising meteor. Analysis shows that, except near the right-angled reflecting point, there is little difference in the velocities derived by using the different assumptions as to the mode of production of the whistle.

11. The Behaviour of the Electron Trail after its Formation

Both from the visual appearance of the meteor trail and the mechanism of ionisation, it is to be expected that the electrons are

initially formed in a long column with a radius of the order of the mean free path at the altitude concerned (say 10 cm. at 100 km.). Observations of the scattering and diffraction of radio waves, discussed above, leave little doubt that this primary phenomenon is correctly interpreted.

Immediately after its formation, however, the electron column is subject to complex processes involving diffusion, recombination and turbulent effects due to winds or other causes in the ionosphere. These effects can be studied by observation of the radio echo for as long as it exists from a given trail. This subsequent behaviour of the radio echo is extremely complicated and is now providing one of the most fruitful fields for investigating the physical processes taking place in these local events in the ionosphere. A few of the main problems will be discussed in this section.

(a) *The Problem of Durations.*—The rates of diffusion for the ionised matter in the meteor trails are not known with any accuracy but from ionospheric data it is reasonable to assume that the rate will be of the order of 1 to 4 m./sec. at 100 km. altitude. If we take the recombination coefficient ($N^2\alpha$) to be 10^{-8}, then it can be shown that the effect of recombination in decreasing the electron density in the trail is small compared with the effect of diffusion. If, for example, we consider a trail containing 10^{10} electrons/cm. path and take the radius of the column at the instant of formation of the order of the mean free path, this gives a volume density of about 10^8 electrons/c.c.

By integrating the recombination equation

$$\frac{dN}{dt} = -\alpha N^2$$

we find the density N_1 after 1 second to be of the order of

$$N_1 = 5 \times 10^7 \text{ electrons/c.c.}$$

Due to diffusion, however, the trail will have a diameter of some 4 m. after 1 second and the volume density will have decreased, due to this cause, to the order of 10^5 electrons/c.c.

If, for the moment, we consider that the column expands with radial symmetry then, as an order of magnitude, one can anticipate that the radio echo will last until the diameter of the electron column is comparable with the wavelength, or until the volume density falls below the critical density, according to which of the scattering mechanisms dealt with in § 8 is appropriate. It is evident, therefore, that if these simple processes alone are operative the radio echoes from meteor trails should have durations from a fraction of a second to a second or so ; that a given trail should produce a longer duration

echo on longer radio wavelengths and that the duration should decrease rapidly with increasing altitude.

Until recently the experimental evidence has been extremely confusing. For example, in the case of a given meteor shower of homogeneous velocity, and therefore ionising in a narrow height range, the observed duration of echoes extends from $< \frac{1}{10}$ second to > 60 seconds on a wavelength of 4 m. [1, 19]. The only well-attested relation has been that between wavelength and duration.
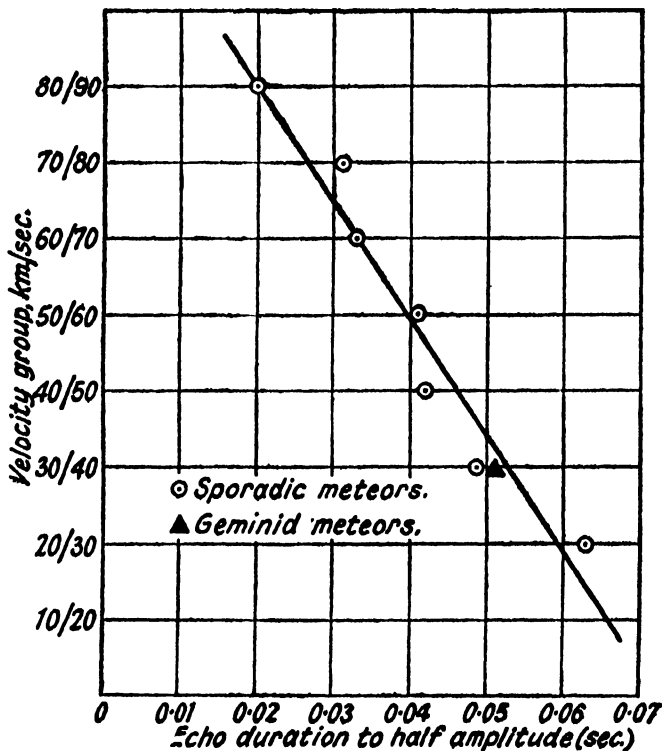
Fig. 10.—The relation between echo duration and velocity measured using a radio frequency of 72 Mc./s.

Simultaneous observations of a given trail on two wavelengths, using apparatus of comparable sensitivities, show the expected increase in duration with wavelength [1].

During the past year it has become possible to make more quantitative measurements of velocity and duration by using the apparatus described in § 10 (b) for studying the diffraction phenomenon. Fig. 10 shows the results of an experiment in which the durations of echoes were measured simultaneously with their velocity

on a wavelength of 4 m. [30]. The bulk of the measurements was made on the sporadic meteor distribution during the autumn of 1948 and the results for a homogeneous velocity group (the 1948 Geminids) are also included. It is evident that these results are in agreement with expectation as regards order of magnitude and also because the high-velocity meteors have shorter durations.

Occasionally, however, in some 10 per cent. of cases, the echo amplitude shows a phenomenal recovery and the echo can be observed for many seconds. For example, Fig. 11, Plate II, shows a photograph of a meteor giving normal zone formation, but with the amplitude increasing again after this initial process.

The mechanism which can occasionally produce echo durations some hundreds of times longer than " normal," and which, moreover, can retain the electron column as a coherent structure for such a period is at present entirely unknown. There is some experimental evidence that the direction of formation of the trail relative to the earth's magnetic lines of force is of considerable influence [1], but it seems that further progress must await the precise determinations of the altitude of the reflecting point from the trail in conjunction with velocity and duration measurements.

(b) *Fluctuations.*—The echoes with abnormally long duration referred to above show very complex and violent fluctuations in intensity during their life. These fluctuations begin as soon as the trail is formed ; in fact, in some cases even during the Fresnel zone formation, thus obscuring the details of the diffraction pattern. It appears that the trail either gives a normal Fresnel zone pattern and produces a short-lived radio echo, of the type measured for the plots in Fig. 10, or produces an abnormally long-duration, fluctuating echo. There are very few cases of long-duration echoes with steady amplitude or a smooth decay to zero.

Most of our existing knowledge of these fluctuations comes from the technique of Davies and Ellyett [23, 24] mentioned in § 10 (b) ; and has been described in detail by Ellyett [31]. Apart from the Fresnel zone fluctuations there appear to be two other types present in the long-duration echoes :

(i) A very high-speed amplitude fluctuation of random period $\sim \frac{1}{10}$ second which begins immediately the trail is formed and continues for the whole life of the echo. An example of this fluctuation is shown in Fig. 12, Plate II.

(ii) A much slower-period fluctuation which emerges after some 20 seconds of the echo life and increases in period with time from $\sim \frac{1}{2}$ second to about 1 second after 60 seconds life.

Continuous histories of these long-duration echoes were obtained

by Ellyett during the 1949 Perseid shower, on two wavelengths (4 m. and 8 m.) simultaneously. The high-speed fluctuation shows no correlation between the two wavelengths. It is not yet known whether correlation exists between the slower-period fluctuations.

The cause of these fluctuations is at present obscure. An attractive suggestion is that they are associated with the radial expansion of the electron column, but a column of electrons with a gaussian distribution across its diameter would produce an echo steadily decaying to zero, without fluctuations, as it diffuses. In fact, it is difficult to see how these long echoes can be associated with normally diffusing trails, since after, say, 20 seconds the electron density would become far too attenuated to produce any type of echo. The most plausible suggestions are that the fluctuations are the result of turbulence in the ionosphere produced by winds or some other mechanism. For other reasons Ratcliffe [32] has concluded that turbulent effects exist which would cause fluctuations of the correct order of magnitude.

There are other phenomena not yet explained, such as the range drifts of some of the long-duration echoes observed by Hey and Stewart [15] and later by Millman and McKinley [16], and the occasional complex echo patterns which have been observed by many workers, especially on the lower frequencies. A phenomenological explanation of these types of phenomenon has been proposed by Millman and McKinley [16], who suggest that the initial columnar form rapidly segregates into electron clusters at various points along the original trail, due to the existence of favourable zones in the ionosphere.

It would appear, however, that the central problem is to find the mechanism which can maintain a sufficient electron concentration for periods of a minute or more against the normal forces of diffusion. It should then be possible to form more definite ideas as to the cause of the fluctuations and other phenomena.

12. OTHER PROBLEMS

There are various other problems associated with meteor ionisation which should come within the scope of this survey—such as the relation of the ionisation to the Sporadic E effects in the E region—which have been omitted because little progress has been made since previous surveys [1].

Finally no attempt has been made to discuss the vital contributions which are being made to meteor astronomy through the ability to study the primary meteoric phenomena unhampered by daylight or cloud.

13. ACKNOWLEDGMENTS

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THE RÔLE OF HIGH-ENERGY PHOSPHATE BONDS IN BIOSYNTHESIS

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THE conception that biosyntheses take place by a reversal of the degradations effected *in vitro* by isolated enzymes must be qualified in the light of recent work on the thermodynamics of bio-reactions and of our knowledge of the rôle of phosphate bonds in the energy economy of the cell. The purpose of the present article is to set out briefly the thermodynamic considerations which govern our present approach to biosynthesis and on this basis to consider the function of phosphate bonds. The introductory sections deal in an elementary way with the relevant aspects of enzyme reaction kinetics. This leads to a consideration of *in vitro* enzymic syntheses and of those synthetic reactions which proceed *in vivo* by being part of a reaction chain leading over-all to a liberation of energy. The inability of these processes to account for the *in vivo* accumulation of energy-rich molecules is taken as the starting point for a discussion of the significance of phosphate bonds as energy carriers enabling energy liberated in degradations to be spatially transferred to the synthetic centres of the cell. The importance of phosphate bonds in biosynthesis is further emphasised by a consideration of the evidence that the main biochemical pathways of energy liberation have as their result the generation of such bonds and by the growing realisation of the wide range of synthetic reactions in which they participate.

The term " synthesis " as applied in organic chemistry merely means the conversion of one substance into another more complex substance regardless of the thermodynamic considerations. In biology the term " synthesis or assimilation " implies reactions which lead to the formation of substances of higher potential energy content (Kalckar, 1941). Thermodynamically a process can be described as having a negative $(-\varDelta F)$ or a positive $(+\varDelta F)$ change

in free energy. If ΔF is negative the reaction is able to produce work (exergonic reaction) ; if ΔF is positive then work must be expended to cause the reaction to occur (endergonic reaction). The free energy change determines the direction and extent of the reaction and the terms exergonic and endergonic are therefore to be preferred to the terms exo- and endo-thermic which relate simply to the heats of reaction. The free energies of formation are related to heats of formation by the relationship

$$\Delta F = \Delta H - T\Delta S$$

where $\qquad$ T = absolute temperature

ΔS = the standard molar entropies

ΔH = change of heat content.

ACTIVATION ENERGY

The hydrolyses of carbohydrates, fats, proteins and amides, catalysed in the living cell by the appropriate enzymes, are exergonic reactions, e.g. :

$$\text{HOOC.CH(NH}_2).\text{CH}_2.\text{CONH}_2 + \text{H}_2\text{O} \underset{}{\overset{\text{asparaginase}}{\rightleftharpoons}} \text{HOOC.CH(NH}_2).\text{CH}_2.\text{COONH}_4$$

asparagine $\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad$ ammonium aspartate

ΔF (at pH 7·0) = – 3460 cals. (McRary 1942)

In the absence of the specific enzyme and within certain limits of temperature and pH asparagine is stable in solution, i.e. it does not undergo spontaneous hydrolysis at a measurable rate. Energy is required to initiate the reaction. Despite the fact that the hydrolytic reaction releases energy, energy must first be supplied. This energy is required to " activate " the molecules and is termed the activation energy. Generally an activation energy is required in all bimolecular reactions. A molecule must change from the " passive " to the " activated " state in order to react and once initiated the reaction proceeds with a finite velocity, i.e. the molecules do not all react simultaneously but only those which at any given moment are activated. The number of molecules undergoing chemical change per second (the velocity coefficient, k, when the concentration of each reactant is unity) $= e^{-E/RT} \times$ constant A,

where $\qquad e^{-E/RT}$ = the Boltzmann factor

E = the energy of activation (cal. per gm./mol.)

R = the gas constant (1·9869 cals. per degree)

T = the absolute temperature.

The activation energy is the excess kinetic energy possessed by the reacting molecules and can be experimentally determined by plotting the log of the velocity constant (k) against the reciprocal of T when

the slope of the line multiplied by R gives — E.   Where two or more molecules react together the reaction will only occur when such activated molecules collide and in the equation given above the constant A is a collision or frequency factor. The energy barrier represented by the activation energy can be represented diagrammatically as in Fig. 1.
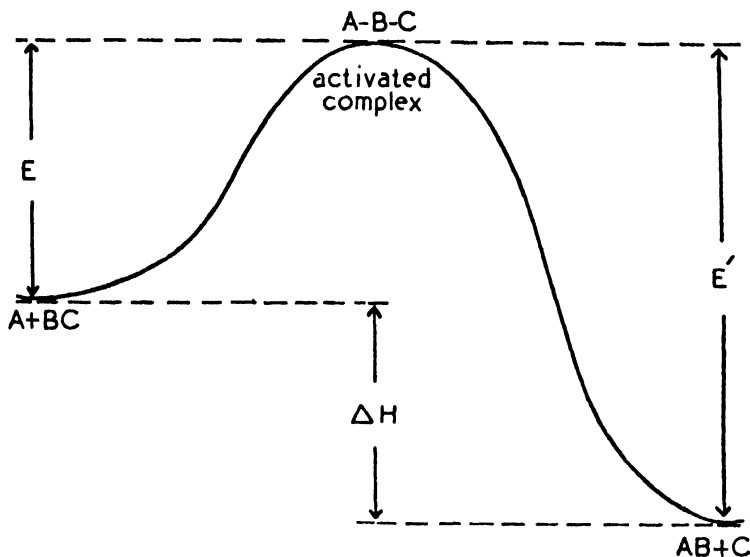
Fig. 1.—Diagrammatic representation of the energy levels involved in the enzyme catalysed reaction

$$A + BC \rightleftharpoons AB + C$$
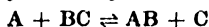
where :   E = activation energy of the forward reaction,
E′ = activation energy of the reverse reaction,
ΔH = change in heat content, — for the forward reaction and
+ for the reverse reaction.

From the Arrhenius equation it follows that E can be calculated from the temperature coefficient of the reactions.

$$k_2 = k_1 e^{\frac{E}{R}\left(\frac{T_2 - T_1}{T_1 T_2}\right)}$$

$$E = \frac{R(T_1 T_2)}{T_2 - T_1} \ln \frac{k_2}{k_1}$$

where k_1 = velocity constant at $T_1°$

$k_2 =$,,   ,,   at $T_2°$

$\dfrac{k_2}{k_1}$ = temperature coefficient, where $T_2 = T_1 + 10°$.

Temperature coefficients for most enzyme catalysed reactions

when measured over the range 20–30° C. fall within the range 1·25 to 2·5, corresponding to energies of activation ranging from 3900 to 16,100 cals. per mol (Sizer 1943). The energy of activation for sucrose inversion by acid calculated in this way gives at 25° C. the value 25,560 cals. per mol. (Lamble and Lewis, 1915). The temperature coefficient (25–35°) for the enzyme (yeast saccharase) catalysed inversion of sucrose is given as 1·61 (Nelson and Bloomfield, 1924) corresponding to an E value of about 8700 cals. Enzymes in common with other surface catalysts lower considerably the activation energy. A bimolecular reaction with E less than 20,000 cals. per mol. will have a measurable velocity within the physiological temperature range, but with values of E above this level temperatures beyond the upper limit of the physiological range will be required for activation. Enzymes by lowering the activation energy make possible biochemical reactions which in their absence will only proceed under physical or chemical conditions incompatible with life.

The Reversibility of Enzyme-catalysed Reactions

Reactions characterised by low energies of activation and by small changes in free energy will be readily reversible. It has been shown that a number of enzyme reactions are reversible and this may apply to enzyme reactions in general. The enzyme will then catalyse both the forward and reverse reaction by reducing both E and E' (energies of activation of the forward and reverse reaction) to a similar extent. The position of equilibrium will therefore be unaffected and only the rate of achievement of the equilibrium will be speeded up. Where the forward reaction is exergonic the back reaction will proceed at a lower velocity (a smaller number of molecules will be activated per second) and the greater the free energy change (ΔF) the more will the position of equilibrium lie in the direction decreasing the free energy of the system. It has been shown (Lewis and Randall, 1923) that the following relationship applies

$$\Delta F = - RT \ln K = - 4{\cdot}58T \log K$$

where   K = the equilibrium constant.

The application of this equation can be illustrated by considering the reaction

$$NH_4^+ \quad + \text{ fumarate''} \quad \rightleftharpoons \quad l\text{-aspartate'}$$
$$\begin{matrix} -\ 18{,}410 & -\ 143{,}430 & -\ 165{,}760 \\ \text{cals.} & \text{cals.} & \text{cals.} \end{matrix}$$
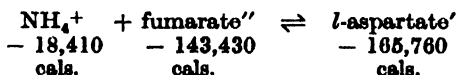
catalysed by aspartase. Using data for the free energies of formation of the ions at 37° C. (Borsook and Huffman, 1933), as shown above, the free energy change (ΔF_{310}) calculated from the thermal

data is -3920 calories.   The equilibrium established in this reaction when catalysed by the aspartase of *B. coli* (Quastel and Woolf, 1926) at 37° C. and pH $7\cdot4$ was

$$\underset{(0\cdot028 \text{ M.})}{NH_4^\cdot} + \underset{(0\cdot028 \text{ M.})}{\text{fumarate}''} \quad \rightleftharpoons \quad \underset{(0\cdot072 \text{ M.})}{l\text{-aspartate}'}$$
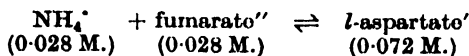
From which K can be calculated taking into account the appropriate activity coefficients thus :

$$K = \frac{(0\cdot072)(0\cdot7)}{(0\cdot028)(0\cdot7)(0\cdot028)(0\cdot22)} = 417$$

from which the ΔF_{310} calculated from the Lewis and Randall equation has the value -3720 calories.

The Lewis and Randall equation explains why *in vitro* many enzymes appear to catalyse only the degradation of their substrates and why for reactions with a large ΔF this degradation appears to be complete.   Thus the oxidative deamination of *d*-alanine by the *d*-amino acid oxidase of animal tissues :

$$d\text{-alanine}^\cdot + \tfrac{1}{2}O_2 \longrightarrow \text{pyruvate}' + NH_4^\cdot$$
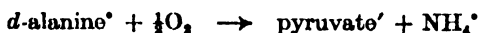
has $\Delta F_{298} = -39{,}470$ cals. and

$$K = \frac{(\text{pyruvate}')(NH_4^\cdot)}{(d\text{-alanine}^\cdot)i\tfrac{1}{2}O_2)} = 10^{28\cdot4}$$

If however the reaction is reversible it is moving to equilibrium and *in vivo* the enzyme will be capable of synthesising the amino-acid, provided that the cell is able to effect a continuous removal of the synthesised material from the sphere of reaction.   The possibility that enzymes which *in vitro* effect what appears to be a complete degradation of their substrates may *in vivo* be responsible for their synthesis was first clearly visualised by Tammann (1892) and Van't Hoff (1898).   Evidence for the reversibility of certain enzyme-catalysed hydrolyses has been obtained by A. C. Hill (1898), Bourquelot *et al.* (1911–19) and subsequent workers.

In Vitro Enzymic Syntheses

Bourquelot and Bridel (1911–12) synthesised and isolated in crystalline form β-ethyl-glucoside by the interaction of glucose and 85 per cent. ethyl alcohol in the presence of emulsin.   By a similar procedure other β-glucosides were synthesised in the presence of emulsin and the concentration of glucoside at equilibrium was shown to be affected by the percentage of alcohol present (Bourquelot and Verdon, 1913).   Kastle and Loevenhart (1900), Pottevin (1904), Welter (1911) and Armstrong and Gosney (1914) have synthesised esters of fatty acids by lipase acting in the absence of water.

Wastaneys and Borsook (1930) and other workers have reported the synthesis of protein-like material (plastein) when mixtures of amino-acids were treated with proteinases and oxygenated or treated with oxidising agents. These reported syntheses of protein have not proved capable of repetition in the hands of other workers (Linderstrøm-Lang and Johansen, 1939 ; Strain and Linderstrøm-Lang, 1939). It was contended by Wastaneys, Borsook and others that the reduced form of the enzyme was active in promoting protein hydrolysis and the oxidised form in promoting synthesis. There is no justification for this view. The activity of papain and other plant proteinases as judged by their hydrolytic activity is dependent upon the presence of free sulphydryl groups and treatment with oxidising agents only serves to inactivate the enzyme.

The ability of proteolytic enzymes to synthesise the peptide linkage is, however, clear from the work of Bergmann et al. Borsook and Dubnoff (1940) have calculated that the free energy change on hydrolysis of the peptide bond in alanylglycine in aqueous solution at 25° C. is − 4000 cals., corresponding to K (hydrolysis) = 866. The position of equilibrium starting with an initial concentration of 0·1 M. peptide is at 99·99 per cent. hydrolysis, or with an initial concentration of 1·0 M. at 99·88 per cent. hydrolysis. The equilibrium therefore lies almost entirely on the side of hydrolysis and the *in vitro* synthesis of peptides from their constituent amino-acids by proteolytic enzyme will only be possible if the solubility of the synthetic product is smaller than its concentration at equilibrium. Bergmann and Behrens (1938) found that, when cysteine-papain, at 40° C., was added to a solution containing equivalent amounts of acetyl-*DL*-phenylalanylglycine and aniline, then after several minutes a copious crystallisation of acetyl-*L*-phenylalanylglycine anilide occurred. Making use of the low solubility of the peptide anilides, Behrens and Bergmann (1939) demonstrated the enzymic formation of genuine peptide bonds by reactions such as :

Benzoyl-*L*-phenylalanylglycine + glycine anilide →
Benzoyl-*L*-phenylalanylglycylglycine anilide
Carbobenzoxy-*L*-phenylalanylglycine + glutamic acid anilide →
Carbobenzoxy-*L*-phenylalanylglycylglutamic acid anilide
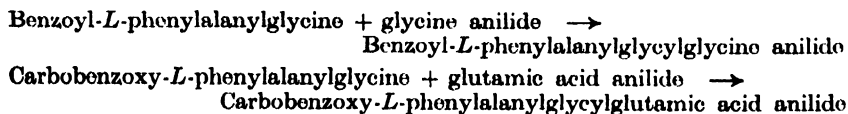
In these peptide syntheses, therefore, the energy required for peptide synthesis comes from the process of crystallisation whereby the synthetic product is removed from the sphere of reaction. The synthetic endergonic reaction should also continue in homogeneous solution if the synthetic product could be removed by forming the substrate of a second exergonic reaction, *i.e.* by the existence of a coupled reaction sequence. It has frequently been observed that

peptides which are perfectly stable in contact with a certain proteolytic enzyme are sometimes attacked by the same enzyme after a second peptide or a complex mixture such as casein or blood serum has been added. Behrens and Bergmann (1939) found that glycyl-L-leucine was not hydrolysed by cysteine-activated papain, but was hydrolysed when acetyl-DL-phenylalanylglycine was added to the solution. Equimolecular amounts of the two peptides in the presence of papain combine by an equilibrium reaction to give a small amount of the tetrapeptide acetyl-L-phenylalanylglycylglycyl-L-leucine. The tetrapeptide is at once acted upon by the enzyme and first an L-leucine and then a glycine residue is released. The result is a hydrolysis of glycyl-L-leucine, but it is accomplished by a series of three reactions, the driving force for the first synthetic reaction being provided by the subsequent enzyme hydrolysis of the acetyl tetrapeptide :

> acetyl-DL-phenylalanylglycine + glycyl-L-leucine
⇅
acetyl-L-phenylalanylglycylglycyl-L-leucine
⇅
acetyl-L-phenylalanylglycylglycine + L-leucine
⇅
− acetyl-L-phenylalanylglycine + glycine

SYNTHESIS BY COUPLING WITH AN EXERGONIC REACTION CHAIN

The decarboxylations of pyruvic and oxalacetic acids are catalysed respectively by the enzymes carboxylase and oxalacetic carboxylase. In experiments with radioactive carbon dioxide Carson *et al.* (1941) have obtained evidence for the reversibility of pyruvic decarboxylation. Werkman and Wood (Werkman and Wood, 1942 ; Kalnitsky and Werkman, 1944) have obtained evidence that the heterotrophic assimilation of carbon dioxide characteristic of many micro-organisms involves a reversal of oxalacetic acid decarboxylation. This Wood-Werkman reaction also seems to be involved in organic acid synthesis by the green plant (Ruben and Kamen, 1940 ; Bonner and Bonner, 1948). The carboxylation of pyruvate to oxalacetate is markedly endergonic, as shown by the calculated free energies of formation (38° C.) of the reactants (Evans *et al.*, 1943).

$$\text{pyruvate}' + \text{HCO}_3' \rightleftharpoons \text{oxalacetate}'' + \text{H}_2\text{O}$$

− 106,460 cals.	− 139,200 cals.	− 184,210 cals.	− 56,200 cals.

$$\Delta F_{311} = + 5250 \text{ cals.}$$

$$\mathbf{K} = \frac{(\text{oxalacetate}'')}{(\text{pyruvate}')(\text{HCO}_3')} = 0.2 \times 10^{-3}$$

The equilibrium therefore lies almost entirely on the side of decarboxylation. *In vivo* the fixation of carbon dioxide by this reaction must imply its coupling with an exergonic reaction or chain of reactions. Carbon dioxide fixation by pyruvate has been shown to be coupled with oxidation of lactate and with formation of succinate, and on this basis Ochoa (1946) has suggested that the fixation reaction is linked with the reaction chain as shown (where DPN = Co-enzyme I, diphosphopyridine nucleotide) :

ΔF for forward reaction

$$\text{pyruvate} + CO_2 \underset{\text{carboxylase}}{\overset{\text{oxalacetic}}{\rightleftharpoons}} \text{oxalacetate} \qquad + 5250 \text{ cals.}$$

$$\text{oxalacetate} + DPN.H_2 \underset{\text{dehydrogenase}}{\overset{\text{malic}}{\rightleftharpoons}} L\text{-malate} + DPN \qquad - 8300 \text{ cals.}$$

$$L(+)\text{lactate} + DPN \underset{\text{dehydrogenase}}{\overset{\text{lactic}}{\rightleftharpoons}} \text{pyruvate} + DPN.H_2 \qquad + 4600 \text{ cals.}$$

$$+ 1550 \text{ cals.}$$
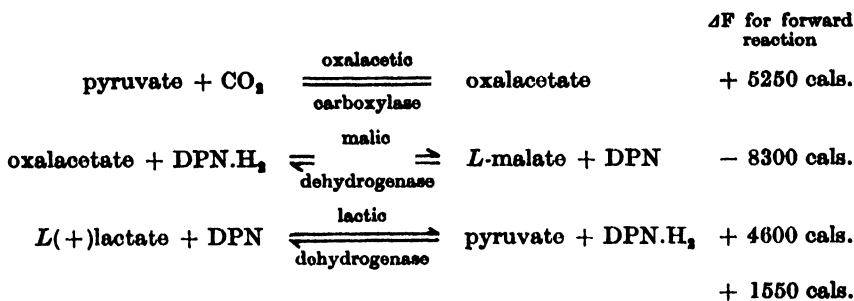
$$K = \frac{(L\text{-malate}'')}{(L\text{-lactate}')(HCO_3')} \simeq 0.1$$

If further malate was converted to fumarate and the fumarate reduced to succinate we have :

$$+ 1550 \text{ cals.}$$

$$L\text{-malate} \overset{\text{fumarase}}{\rightleftharpoons} \text{fumarate} \qquad + 705 \text{ cals.}$$

$$\text{fumarate} + 2H \underset{\text{fumaric reductase (?)}}{\overset{\text{hydrogenase} +}{\rightleftharpoons}} \text{succinate} \qquad - 20,450 \text{ cals.}$$

$$- 18,195 \text{ cals.}$$
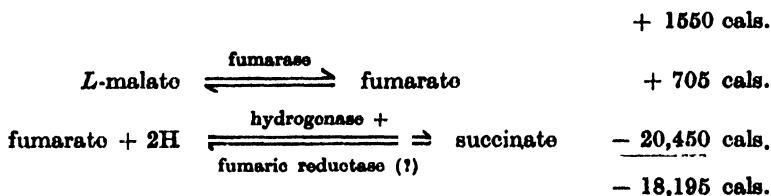
Thus if carbon dioxide fixation is linked with a reaction chain ending with succinate formation it would proceed almost to completion. The oxalacetate is removed as synthesised by a series of reactions which proceed over-all with a marked decrease in free energy. The synthetic (endergonic) reaction is achieved by coupling it with energy yielding (exergonic) reactions in a biochemical reaction chain.

The action of the dehydrogenases can be represented by the general reaction

$$\underset{\substack{\text{oxidisable} \\ \text{substrate}}}{AH_2} + \text{Co-enzyme} \underset{\substack{\text{apoenzyme} \\ \text{(dehydrogenase)}}}{\overset{\text{specific}}{\rightleftharpoons}} \underset{\substack{\text{oxidised} \\ \text{substrate}}}{A} + \text{reduced Co-enzyme}$$
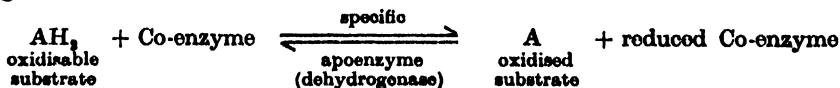
The reversible nature of these reactions is supported by many *in vitro* experiments. Calculations of the free energy changes (ΔF)

involved have been made either from the equilibrium constants or from the potential difference between the two reacting systems in the oxido-reduction using the relationship

$$- \Delta F = n F \Delta E$$

where ΔE = potential difference in volts

n = number of electrons involved

F = the faraday (96,500 coulombs)

ΔF = change in free energy in joules (1 calorie = 4·18 joules).

The following may be cited as examples :

			ΔF (cals.) for forward reaction
$L(+)$lactate + DPN.	lactic dehydrogenase	pyruvate + DPN.H$_2$	+ 4600
$L(+)$malate + DPN.	malic dehydrogenase	oxalacetate + DPN.H$_2$	+ 8300
ethyl alcohol + DPN.	alcohol dehydrogenase	acetaldehyde + DPN.H$_2$	+ 5000
3-phosphoglyceraldehyde + phosphate + DPN	triosephosphate dehydrogenase	1:3-diphosphoglyceric acid + DPN.H$_2$	+ 400

Therefore, except in the case of the triosephosphate dehydrogenase reaction, the equilibrium lies almost entirely to the left, *e.g.*

$$K = \frac{(\text{lactate})(\text{DPN.})}{(\text{pyruvate})(\text{DPN.H}_2)} = 14 \cdot 1 \times 10^4 \text{ at pH } 7 \cdot 4$$

(Euler, Günther and Hellstrom, 1937).

Oxidation will therefore only continue if the oxidised product is removed in a linked reaction or a mechanism exists to re-oxidise the reduced co-enzyme so as to maintain a very low level of reduced co-enzyme. Under anaerobic conditions the continued oxidation of 3-phosphoglyceraldehyde will be maintained by the regeneration of DPN, either in the reduction of pyruvate via acetaldehyde to alcohol (as in yeast fermentation) or to lactate (as in muscle glycolysis). Under aerobic conditions the oxidation of pyruvate via the tricarboxylic acid cycle (modified Krebs-Johnson cycle) will require constant oxidation of reduced co-enzyme by the flavoprotein-cytochrome system. The equilibrium

$$\text{DPN.H}_2 \rightleftharpoons \text{DPN. } + 2e + 2\text{H}^+$$

will depend on the oxidation–reduction potential between the reacting systems in the oxidation chain linking the phosphopyridine nucleotides (co-enzymes) with molecular oxygen. Fig. 2 compiled

from data presented by Clark (1938) and Ball (1939) shows the E_0' values in volts and ΔF in calories calculated from the equation $-\Delta F = nF\Delta E$.
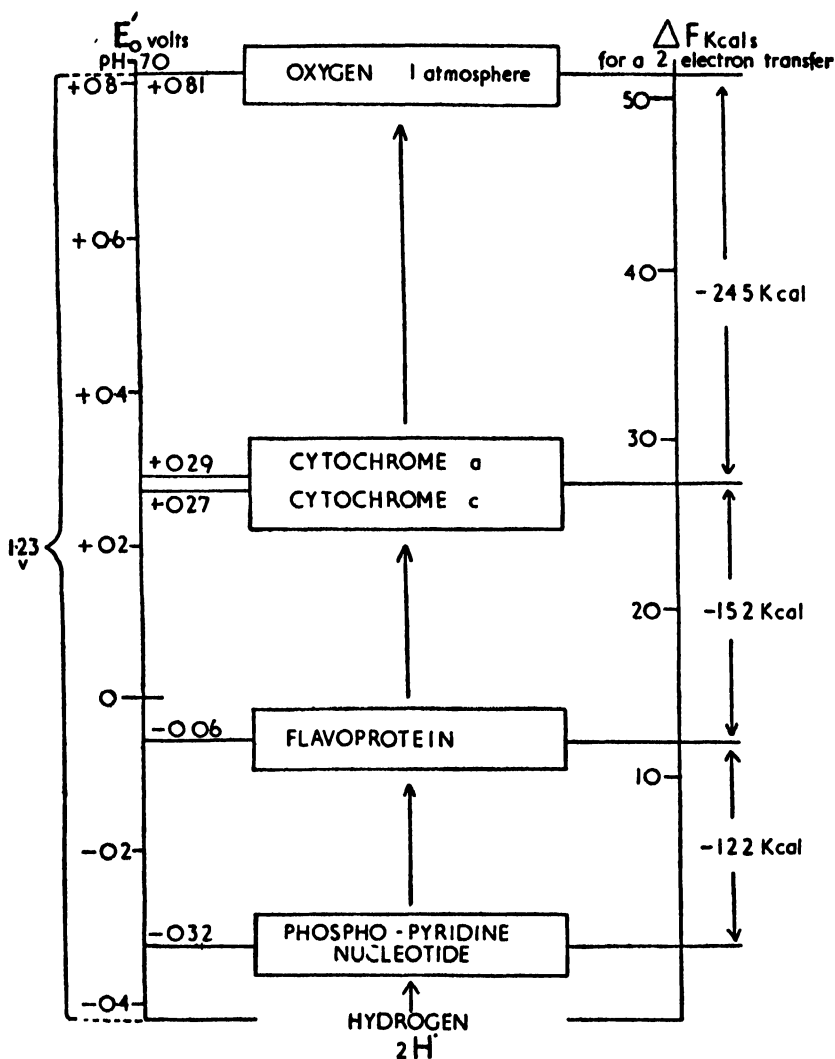
FIG. 2.—Oxidation reduction potentials and free energy changes involved in the transfer of two hydrogen electrons from reduced phosphopyridine nucleotide (co-enzyme) to oxygen.

Each oxidation step in this chain proceeds with a large fall in free energy and therefore the phosphopyridine nucleotide will be maintained almost completely in the oxidised form. The endergonic

dehydrogenations cited above are therefore maintained in the direction of oxidation by coupling with the exergonic reactions which complete the hydrogen transport train.

THE RETENTION OF FREE ENERGY BY SYNTHESIS OF ENERGY-RICH PHOSPHATE BONDS

In contrast with the other dehydrogenase reactions cited, the triosephosphate dehydrogenase reaction is characterised by a small change in free energy. Ochoa (1946) gives the value $\Delta F = ca. + 400$ cals. for the oxidation reaction calculated from the equilibrium constant. The data of Meyerhof and Junowicz-Kocholaty (1943) indicates for the reaction

3-phosphoglyceraldehyde + DPN. $\rightleftharpoons$ 3-phosphoglyceric acid + DPN.H$_2$

a ΔF value of $ca. - 10,000$ cals.

The small energy change involved in the reaction :

3-phosphoglyceraldehyde + phosphate + DPN. $\rightleftharpoons$
1:3-diphosphoglyceric acid + DPN.H$_2$

is therefore due to coupling of the oxidation with the creation of a carboxyl-phosphate bond (.COO$\sim$ph). In the absence of adenosine diphosphate (ADP) the 1:3-diphosphoglyceric acid accumulates, but in its presence a transphosphorylation takes place (Negelein and Brömel, 1939)

1:3-diphosphoglyceric acid + ADP. $\rightleftharpoons$ 3-phosphoglyceric acid + ATP.

The carboxyl-phosphate group has a free energy content of the order of 10,000 cals. (0·24 v.). This high energy content of the COO$\sim$ph in the diphosphoglyceric acid is correlated with its instability (half-time of decomposition 27 minutes). The retention of free energy by the simultaneous synthesis of COO$\sim$ph has converted an otherwise markedly exergonic reaction into one involving only a small free energy change, and makes possible the generation of a pyrophosphate bond of adenosine triphosphate (ATP) for this oxidative step in glycolysis. A similar mechanism is involved in the generation of the second pyrophosphate bond arising during the glycolytic breakdown of triosephosphate. This second pyrophosphate bond is formed by a transphosphorylation reaction with enolphosphopyruvate

$$\text{enolphosphopyruvate + ADP} \xrightleftharpoons[\text{transphosphorylase}]{\text{phospho-eno}} \text{pyruvate + ATP}$$
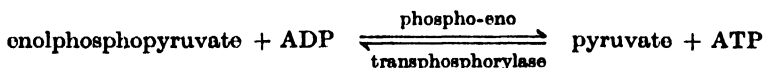
This reaction has been shown to be reversible (Lardy and Ziegler, 1945), although the equilibrium corresponds to almost complete dephosphorylation of enolphosphopyruvate ($\Delta F = ca. - 3000$ cals.).

The origin of the enolphosphopyruvate from 2-phosphoglycerate can be represented

$$
\begin{array}{c c c}
CH_2OH & & CH_2 \\
| & \xrightarrow[+H_2O]{\substack{\text{enolase} \\ -H_2O}} & \| \\
CHO-ph & \rightleftharpoons & C.O\sim ph \\
| & & | \\
COOH & & COOH \\
\text{2-phospho} & & \text{enolphosphopyruvic acid} \\
\text{glyceric acid} & &
\end{array}
$$
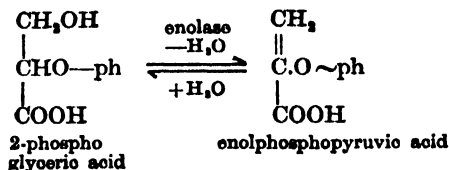
This reaction involves very little change in free energy and is readily reversible. The energy-rich enol-phosphate bond $(C{:}C.O\sim ph)$ arises from an intramolecular redistribution of energy and the free energy retained by its formation can be calculated by consideration of the equations (a), (b) and (c).

(a) hydrolysis of the ester phosphate bond in 2-phosphoglycerate

$$\Delta F$$

$$
\begin{array}{c c c}
CH_2OH & & CH_2OH \\
| & & | \\
CHO-ph + H_2O & \rightarrow & CHOH + H_3PO_4 \qquad - 3000 \text{ cals.} \\
| & & | \\
COOH & & COOH \\
\end{array}
$$
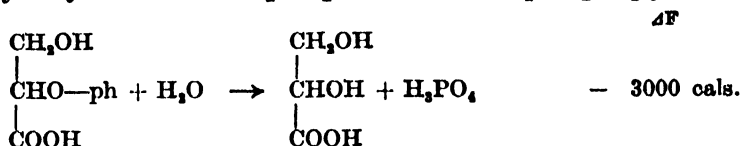
(b) dehydration of glycerate to pyruvate (Lipmann, 1946).

$$\text{glyceric acid} \rightarrow H_2O + \text{pyruvic acid} \qquad - 12{,}950 \text{ cals.}$$

Therefore

(c)

$$\text{2-phosphoglyceric acid} \rightarrow \text{pyruvic acid} + \text{phosphate} \qquad \underline{- 15{,}950 \text{ cals.}}$$
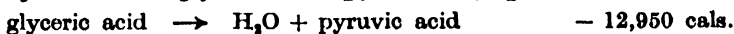
A free energy content of ca. 16,000 cals is retained in the $C{:}C.O\sim ph$ bond, and an otherwise markedly exergonic reaction is rendered reversible.

A further example of the conservation of chemical energy in the form of energy-rich phosphate bonds $(\sim ph)$ is provided by the acetic fermentation of *B. coli*. The hydroclastic breakdown of pyruvate to acetate + formate :

$$CH_3.CO.COO' + H_2O \rightarrow CH_3.COO' + HCOO' + H\cdot$$

is a strongly exergonic reaction $(\Delta F = - 17{,}400 \text{ cals.})$. Cell free extracts of *B. coli*, in the presence of phosphate (Kalnitsky and Werkman, 1943), effect a phosphoclastic breakdown of pyruvate thus :

$$CH_3.CO.COO' + HOPO_3 \rightleftharpoons CH_3.COO\sim PO_3'' + HCOO'$$
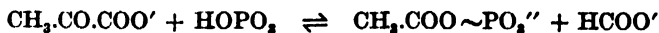
This equilibrium reaction is much less markedly exergonic than the hydroclastic split and has $\Delta F = - 2500$ cals., so that

$$K = \frac{(\text{pyruvate}) \times (\text{phosphate})}{(\text{acetyl phosphate}) \times (\text{formate})} = \text{ca. } 10^{-2}.$$

In the absence of adenosine mono- (AMP) or diphosphate (ADP) the acetyl phosphate accumulates. In the presence of AMP or ADP a transphosphorylation occurs leading to the synthesis of an energy-rich polyphosphate bond. The reaction :

$$CH_3.COOPO_3'' + ADP \rightleftharpoons CH_3.COO' + ATP$$

has $\Delta F = -2400$ cals.

THE ESTER PHOSPHATE BOND

The energy-rich phosphate bonds ($\sim$ph) considered in the above examples all have energy contents ranging from 10,000–16,000 cals. (Lipmann, 1941). Compared with such bonds the more stable ester-phosphate linkages such as occur in phosphoglycerate and in the hexose phosphates yield on hydrolysis ca. 3000 cals. These ester-phosphate linkages are, however, also of importance as mechanisms for the conservation of energy and their formation renders certain biochemically important reactions readily reversible.

The breakdown of glycogen in yeast, muscle and other animal tissues has been shown to be associated with esterification of inorganic phosphate and, conversely, its synthesis to be associated with liberation of inorganic phosphate (cf. SCIENCE PROGRESS, 1946, **136**, 779). From these and other tissues Cori and his co-workers (1936–38) have prepared enzymes (phosphorylases) which in the presence of a trace of adenosine monophosphate (AMP) catalyse a phosphorolysis of glycogen or starch with formation of glucose-1-phosphate (Cori ester). The reaction can be represented (Sutherland, Colowick and Cori, 1941)

$$\text{glycogen} + \text{phosphate} \xrightleftharpoons[23\%]{77\%} \text{glucose-1-phosphate}$$
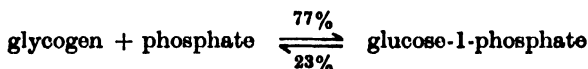
Kiessling (1939) calculated that :

$$K = \frac{\text{inorganic phosphate}}{\text{glucose-1-phosphate}} = 5\cdot2$$

corresponding to a $\Delta F = +1100$ cals.

A synthetic polysaccharide of the glycogen type was synthesised from glucose-1-phosphate in the presence of phosphorylase and a catalytic amount of glycogen to act as a " starter " (Kiessling, 1939 ; Bear and Cori, 1941).

Hanes (1940) has isolated a phosphorylase from potatoes and peas, for which AMP is not an essential co-enzyme. Using this enzyme, Hanes has synthesised a polysaccharide closely resembling in properties and X-ray structure (Astbury, Bell and Hanes, 1940) the amylose fraction of starch. More recently evidence has been

obtained for the presence in potato of a second enzyme (Q-enzyme) which, acting in conjunction with purified phosphorylase (P-enzyme), effects the conversion of glucose-1-phosphate into a polysaccharide closely resembling the amylopectin fraction of starch (Haworth, Peat and Bourne, 1944 ; Bourne and Peat, 1945).

Starch may undergo either hydrolytic or phosphorolytic breakdown. The hydrolysis of starch by amylases leads ultimately to maltose and this may be further hydrolysed by maltase to free glucose. There is no evidence for the reversibility of this exergonic hydrolysis, and the biological mechanism of synthesis is almost certainly a dephosphorylative condensation in which energy liberated by breakage of ester phosphate linkages becomes stored in the α-glucosidic linkages of the polysaccharide molecule. The reversibility of the phosphorolytic breakdown is due to conservation of the energy liberated as ester phosphate bond energy.

Sucrose is hydrolysed by saccharase (β-fructofuranosidase) to give invert sugar, an equimolecular mixture of glucose and fructose. There is no evidence that sucrose can be synthesised by reversal of this exergonic reaction. A sucrose phosphorylase, free from saccharase and phosphatase action, has been isolated from *Pseudomonas saccharophila* (Doudoroff, 1943 ; Doudoroff, Kaplan and Hassid, 1943) and from *Leuconostoc mesenteroides* (Kagan, Lyatker and Tsvasman, 1942). This catalyses the reaction :

$$\text{sucrose} + H_3PO_4 \rightleftharpoons \text{glucose-1-phosphate} + \text{fructose}$$
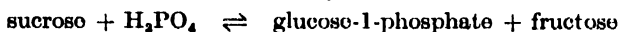
for which

$$K = \frac{(\text{sucrose})(\text{phosphate})}{(\text{glucose-1-phosphate})(\text{fructose})}$$

has been approximately determined at 30° C., and the values obtained were 0·05 (pH 6·6) and 0·09 (pH 5·8) (Doudoroff, 1943). The phosphorolysis therefore proceeds with a smaller decrease in free energy than the hydrolysis. Starting with Cori ester and free fructose, a crystalline product identical with natural sucrose has been synthesised (Hassid, Doudoroff and Barker, 1944). This agrees with the evidence brought forward by Isbell and Pigman (1938) for the existence of an equilibrium between the pyranose and furanose forms of fructose. The total system can therefore be represented

$$\text{sucrose} + H_3PO_4 \underset{\text{phosphorylase}}{\overset{\text{sucrose}}{\rightleftharpoons}} \text{glucose-1-phosphate} + \text{fructofuranose} \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \updownarrow \\ \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \text{fructopyranose}$$
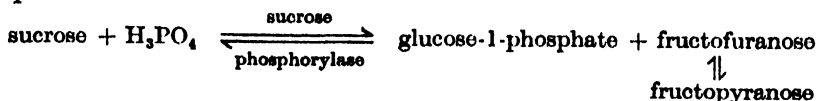
The distribution of sucrose phosphorylase has not yet been systematically studied. There is, however, indirect evidence that

sucrose synthesis in the sugar cane plant involves phosphorylation (Hartt, 1943, 1944) ; and Calvin and Benson (1949), in a study of photosynthesis in *Chlorella pyrenoidosa* using radioactive $C^{14}O_2$, have shown that the first sugar to be formed is a fructose mono-phosphate, followed rapidly by the appearance of a glucose mono-phosphate, and that from these sucrose is synthesised and appears as the first free sugar. The mechanism of sucrose biosynthesis is therefore a further example of the utilisation of ester phosphate bond energy for the synthesis of a glycosidic linkage.

THE GENERATION OF ENERGY-RICH PHOSPHATE BONDS

The formation of energy-rich phosphate bonds ($\sim$ph) not only renders certain reactions readily reversible but constitutes, through transphosphorylation reactions with adenosine pyrophosphate, a mechanism whereby energy can be transferred from energy-liberat-ing to energy-consuming systems. The synthesis of pyrophosphate bonds therefore represents a mechanism whereby the energy liberated by glycolysis and aerobic respiration can be used in biosynthesis. The significance of this mechanism becomes apparent when we consider the quantitative relationship between energy liberation in carbohydrate breakdown and adenosine triphosphate synthesis and when we examine the range of action of adenosine triphosphate as the source of energy for the synthesis of cell constituents.

The overall reaction for the glycolytic breakdown of glucose to ethyl alcohol is :

$$C_6H_{12}O_6 = 2CO_2 + 2C_2H_5OH$$
$$\varDelta F = - 50,000 \text{ cals.}$$
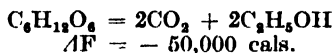
The breakdown of two molecules of triose phosphate by the Embden-Meyerhof reaction sequence (Mann and Lutwak-Mann, 1944) leads to the synthesis of $4 \times \sim$ph in ATP. Two of these bonds are utilised for the synthesis of fructose-1-6-diphosphate (Harden-Young ester) from free glucose prior to its fission by the enzyme aldolase (zymohexase). Therefore during the anaerobic breakdown of glucose some 40 per cent. ($2 \times \sim$ph $=$ ca. 22,000 cals.) of the total free energy available is transformed into phosphate bond energy.

The overall reaction for the aerobic respiration of hexose can be represented :

$$C_6H_{12}O + 6O_2 = 6CO_2 + 6H_2O$$
$$\varDelta F = - 674,000 \text{ cals.}$$
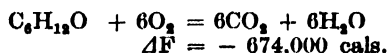
The complete oxidation of pyruvate has been calculated to yield 274,310 cals. per mol. (Ogston and Smithies, 1948). From studies

employing mammalian tissues there has been obtained convincing evidence of the coupling of pyruvate oxidation with phosphorylation. Pyruvate oxidation takes place in mammalian and at least in some plant tissues by the operation of a tricarboxylic acid cycle (Krebs, 1943). Kalckar (1939), using extracts of mammalian kidney, showed that both respiration and the conversion of inorganic to organic phosphate were stimulated by alanine (which would yield pyruvic acid on oxidative deamination), glutamic acid (which would yield α-ketoglutaric acid), citric, malic and fumaric acids. The phosphorylation was not inhibited by fluoride, which blocks normal glycolysis by inhibiting enolase, and therefore resulted directly from oxidation of the added acids. Colowick *et al.* (1940), also using kidney extracts, have demonstrated the association of phosphorylation with oxidation of pyruvic and succinic acids. Ochoa (1943a, 1944) has shown that phosphorylation is associated with oxidation of α-ketoglutarate to succinate, and Muñoz and Leloir (1943) have obtained a similar result in studying the oxidation of malate to oxalacetate. It is therefore possible that energy-rich $COO\sim ph$ is generated during the oxidative steps of the tricarboxylic acid cycle. Quantitative studies by Ochoa (1944, 1943b), using pigeon brain dispersions and heart muscle extracts, indicated that as many as 6 molecules of phosphate were taken into organic combination per molecule of oxygen used. The oxidation of pyruvate can be represented :

$$CH_3CO.COOH + 5O \longrightarrow 3CO_2 + 2H_2O$$

On this basis no less than 15 energy-rich phosphate bonds would appear to be generated per molecule of pyruvate completely oxidised. It is difficult to visualise how this could occur either entirely or even in greater part through phosphorylation of the intermediates in the tricarboxylic acid cycle. This difficulty is emphasised by the established endergonic nature of certain of the oxidative steps in this cycle. The hydrogen transport chain, whereby hydrogen is removed from reduced co-enzyme and ultimately united with oxygen (Fig. 2), is however characterised by a sequence of reactions each making available sufficient energy to synthesise an energy-rich phosphate bond. Lipmann (1946b) has outlined the hypothesis that $3 \times \sim ph$ are generated during the transport of each pair of hydrogen electrons from co-enzyme to oxygen, and this has received experimental support in the researches of Friedkin and Lehninger (1949) and Lehninger (1949). If we assume that only $15 \times \sim ph$ are generated per molecule or pyruvate oxidised, then per molecule of glucose undergoing aerobic respiration we have generated :

By glycolysis 2 × ~ph = 2 × 11,000   = 22,000 cals.
By aerobic oxidation of two molecules of pyruvate
   30 × ~ph = 30 × 11,000   = 330,000 cals.
$$\overline{}$$
                                               352,000 cals.

which represents *ca.* 52 per cent. of the total free energy available. The efficiency with which energy liberated in carbohydrate breakdown is converted into ~ph indicates that, in all probability, the whole of that fraction of the respiratory energy which is utilisable in cell metabolism passes through a stage when it takes the form of phosphate bond energy.

Phosphate bond energy appears to be the direct source of energy for CO_2 assimilation in *Thiobacillus thio-oxidans.* This autotrophic sulphur bacterium effects the oxidation of elementary sulphur according to the equation :

$$2S + 3O_2 + 2H_2O = 2H_2SO_4$$
$$\Delta F = -141,800 \text{ cals.}$$
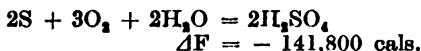
The energy thereby liberated is utilised by the organism to effect a chemosynthesis of carbohydrate from CO_2. Vogler and Umbreit (1942) and LePage and Umbreit (1943) have shown that sulphur oxidation, in the absence of CO_2, is coupled with absorption of phosphate from the medium and synthesis and accumulation of organic phosphorus. Organic phosphorus so accumulated could subsequently be utilised to effect CO_2 assimilation when sulphur oxidation was not proceeding, and under such circumstances inorganic phosphate was liberated. When sulphur oxidation and CO_2 assimilation proceeded concomitantly no accumulation of organic phosphorus occurred. These results constituted strong circumstantial evidence that the energy liberated by sulphur oxidation was converted into phosphate bond energy and that this could be used to effect carbohydrate synthesis from carbon dioxide.

Emerson *et al.* (1944) have put forward the hypothesis that in photosynthesis light energy is converted directly into phosphate bond energy (for each quantum of light absorbed one ~ph is generated), and that energy in this form is utilised in the biochemical reactions involved in CO_2 assimilation. The effect of irradiation on the distribution of phosphorus within the different organic-phosphorus fractions of the cells of *Chlorella* was regarded as supporting this hypothesis. Aronoff and Calvin (1948), in experiments using radioactive phosphate and " grana," leaves and *Chlorella*, have been unable to confirm that any significant changes in phosphorus distribution take place directly as a result of irradiation. Furthermore irradiation of photosynthetic cells in absence of CO_2

does not build up any capacity to effect CO_2 assimilation in a subsequent dark period such as would be expected to occur if light energy was directly converted into phosphate bond energy. The hypothesis also faces a further theoretical objection, for on the basis that 10 quanta are absorbed per molecule of CO_2 reduced ($\Delta F = +$ 130,000 cals.) it seems necessary to postulate the generation of $2 \times \sim$ph per quantum. Such a performance would require the existence of a mechanism whereby the energy of the excited chlorophyll molecule could be divided between two phosphate bonds (Gaffron, 1946). The recent work of Calvin and Benson (1948, 1949) on the assimilation of $C^{14}O_2$ by *Chlorella* does, however, show that phosphorylated intermediates (phosphoglyceric acids, triose phosphates, and hexose phosphates) are involved not only in carbohydrate breakdown but also in carbohydrate synthesis.

THE UTILISATION OF ENERGY-RICH PHOSPHATE BONDS IN SYNTHESIS

Adenosine triphosphate is able to effect the synthesis of hexose phosphates through the agency of the hexokinase of Meyerhof (1927) and therefore is involved in polysaccharide and disaccharide syntheses from free monosaccharides. These reactions are essentially irreversible, due to the large decrease in free energy involved

$$\text{glucose} + \text{ATP} \longrightarrow \text{glucose-6-phosphate} + \text{ADP}$$
$$\Delta F = ca. -8000 \text{ cals.}$$
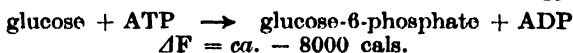
Krebs (1935) has shown that in kidney cortex and brain tissues the synthesis of glutamine is linked with aerobic respiration and that hydrocyanic acid inhibits the synthesis of glutamine to approximately the same degree as it inhibits respiration. Under anaerobic conditions no glutamine synthesis takes place in the tissues and *in vitro* glutamine is completely converted to ammonium glutamate in the presence of the hydrolytic enzyme glutaminase. Speck (1947) and Elliott (1948) have now shown that ATP is the energy donor for glutamine synthesis in animal tissues and Elliott has suggested the intermediate formation of glutamylphosphate (containing the group COO$\sim$ph). Glutamine synthesis therefore appears to take place by a dephosphorylative condensation rather than by a reversal of hydrolysis.

Borsook and Dubnoff (1940). in a study of the metabolism of liver slices, have shown that the synthesis of hippuric acid does not occur when the cell structure is destroyed by maceration or when the respiration of the tissue is inhibited by cyanide. The evidence obtained was regarded as indicating that synthesis of the —CONH group (corresponding in free energy content to the peptide bond ;

ΔF (hydrolysis) $= -3170$ cals.) was not achieved *in vivo* by a reversal of hydrolysis through coupling with an exergonic reaction but by some alternative route. Greenberg *et al.* (1948) have similarly found that, with liver slices or homogenates, protein synthesis (as judged by incorporation of the C^{14} of labelled glycine) requires the simultaneous occurrence of oxidative reactions and is inhibited by cyanide and azide. These observations are not at variance with the suggestion (Lipmann, 1941) that peptide synthesis *in vivo* might involve the synthesis of acyl phosphates of the amino-acids by transphosphorylation from ATP, followed by dephosphorylative condensation. More recently Frantz *et al.* (1948) have shown that dinitrophenol treatment of rat liver slices, receiving isotope labelled *DL*-alanine, inhibits alanine incorporation into proteins while permitting oxygen consumption to continue. The cessation of synthesis of alanine peptide bonds appeared to be due to depletion of energy-rich phosphate donors. More direct evidence for the Lipmann hypothesis is provided by the demonstration (Johnston and Block, 1949) that ATP is active in promoting the synthesis of glutathione in extracts of acetone-dried pigeon liver and that this effect is not due to the intermediate formation of glutamine.

The phosphorus-containing nucleoprotein molecule is a self-duplicating unit presumably because it possesses the ability to transform and accumulate energy within its own molecular structure and to use this energy for the synthesis of similar units. The formation of enzyme proteins is apparently controlled by cytoplasmic self-duplicating nucleoprotein units derived from the genes, and therefore it is possible that energy-rich centres in nucleoprotein units control synthesis of proteins in general. Spiegelman and Kamen (1946, 1947) and Muller (1947) have suggested that nucleoproteins act as agents which funnel energy into the protein synthesising mechanism. Spiegelman and Kamen (1946) have shown, using yeast cells supplied with P^{32}, that when new protein is not being synthesised little transfer of phosphorus from the nucleoprotein (NP) fraction occurs, but that synthesis of new protein is paralleled by a marked transfer of P from the NP fraction. Agents effective in stopping protein synthesis (sodium azide and dinitrophenol) also prevented the flow of P from the NP fraction, suggesting that energy stored as $\sim$ph in the NP fraction is involved in protein synthesis. The fact, however, that other organic P fractions also show a high rate of P exchange during protein synthesis emphasises that the identification of nucleoprotein as the sole or even the main energy donor for protein synthesis awaits further proof (Spiegelman and Kamen, 1947).

The demonstrations of the reversibility of peptide hydrolysis and the enzymatic syntheses of peptide derivatives by proteinases under special *in vitro* conditions does not constitute any *a priori* reason for concluding that petide bond synthesis and ultimately protein synthesis takes place by a simple reversal of the hydrolytic cleavage. The experimental data briefly summarised above seems rather to support the alternative view that a dephosphorylative condensation is involved and that phosphate bond energy drives the *in vivo* synthesis of protein.

The synthesis of neutral fats involves synthesis of the natural long-chain fatty acids and their combination in ester linkage with the trihydric alcohol glycerol. The fact that the natural fatty acids have an even number of carbon atoms has led to the view that C_2 residues from carbohydrates represent the starting point of fatty acid synthesis. This hypothesis is strongly supported by the recent work of Rittenberg and Bloch (1944) on the synthesis of fatty acids from C^{13} and deuterium labelled acetic acid ($CD_3.C^{13}OOH$). From studies of bacterial and animal metabolism there is evidence that acetyl phosphate is involved in acetoacetic acid synthesis. Acetyl phosphate may arise (Lipmann, 1946a) either by a phosphoroclastic split of pyruvate:

$$CH_3.CO.COO' + HOPO_3'' \rightleftharpoons CH_3.COOPO_3'' + HCOO'$$
$$\Delta F = -2500 \text{ cals.}$$
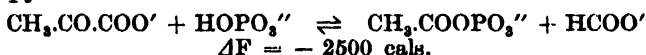
or by reaction of acetate with ATP:

$$CH_3.COO' + ATP \rightleftharpoons CH_3.COOPO_3'' + ADP$$
$$\Delta F = +2400 \text{ cals.}$$
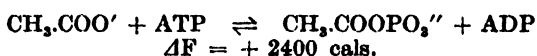
The synthesis of acetoacetate by condensation of acetyl phosphate and acetate is a reversible reaction involving only a small change in free energy as compared with the hypothetical reaction involving condensation of two free acetate groups (Lipmann, 1946a)

$$\Delta F \text{ cals.}$$

$$CH_3.COO' + CH_3.COO' + H_2CO_3$$
$$= CH_3.CO.CH_2.COO' + H_2O + HCO_3' \quad +16,000$$
$$CH_3.COOPO_3'' + CH_3.COO' + H_2CO_3 \rightleftharpoons$$
$$CH_3.CO.CH_2.COO' + H_3PO_4' + HCO_3' \quad +1000$$
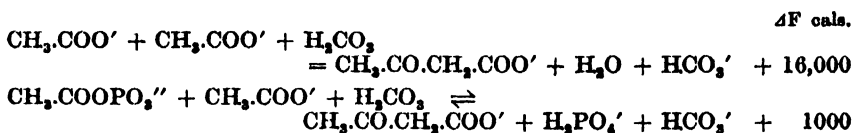
The free energy change involved in this synthesis would be equally favourable if two acetyl phosphate units were involved, and it may be postulated that such a condensation followed by a reversal of β-oxidation is involved in the *in vivo* synthesis of fatty acids (Baldwin, 1947). The condensation of 2 molecules of acetyl phosphate would yield acetoacetyl phosphate and this on β-reduction would give normal butyric acid phosphate, which by condensation with a further molecule of acetyl phosphate followed by β-reduction

would give valeric acid phosphate and so on, yielding in due course the acyl phosphates of long chain saturated fatty acids such as palmitic acid and stearic acid :

$$CH_3.COO{\sim}ph + CH_3COO{\sim}ph \rightleftharpoons CH_3.CO.CH_2.COO{\sim}ph + phosphate$$

β-reduction

$$CH_3.CH_2.CH_2.COO{\sim}ph + CH_3.COO{\sim}ph \rightleftharpoons$$
$$CH_3.CH_2.CH_2.CO.CH_2.COO{\sim}ph + phosphate$$

β-reduction

$$CH_3.CH_2.CH_2.CH_2.CH_2.COO{\sim}ph$$
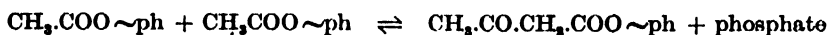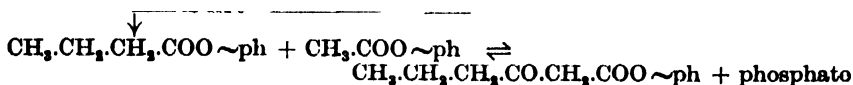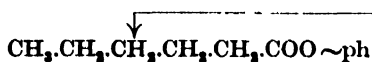
A reversal of this process (fatty acid oxidation) would yield energy-rich phosphate capable of transference to AMP or ADP. Such a synthesis of fatty acid chains from pyruvate by intermediate formation of acetyl phosphate, however, remains hypothetical and the enzyme systems concerned in the postulated dephosphorylative condensation and β-reduction are unknown. In support of such a hypothesis is the evidence that phosphate is apparently essential for both synthesis (Smedley-Maclean and Hoffert, 1923, 1924) and oxidation of fatty acids (Muñoz and Leloir, 1943). Lehninger (1945) has noted activation of fatty acid oxidation by ATP indicating that phosphorylated intermediates are involved. In later work (1946a) it was shown that the oxidation of octanoic acid by rat liver homogenates in presence of Mg^{++}, malonate and ATP gave acetoacetate and (1946b) that heart muscle in presence of fumarate can effect fatty acid oxidation when supplied either ATP or adenosine monophosphate (AMP).

The acyl phosphates of the fatty acids which would arise by the mechanism outlined above may well be involved directly in a dephosphorylative condensation with glycerol as suggested by Lipmann (1941). This mechanism of fat synthesis seems more probable than a simple reversal of lipase catalysed hydrolysis which *in vitro* can only be achieved by reduction of the water concentration to an extent hardly to be expected to occur even at special loci in the cell.

The above discussion has been designed to show that future studies of the mechanisms of biosynthesis must be based on a proper appreciation of the kinetics and thermodynamics of enzyme catalysed reactions and of the part played by phosphate bonds in the liberation, storage, distribution and utilisation of energy in the cell. These considerations have however, of necessity, been treated

without reference to the existence of a structural organisation within the cell, whereby a spatial arrangement of enzymes is maintained and directed synthesis achieved in a way impossible in the simpler systems which have been used in many of the investigations upon which our knowledge of biochemical reactions is founded. It is, however, to be expected that the range of *in vitro* enzymic syntheses will gradually approach the synthetic ability of the cell as we gain increasing knowledge of the operative enzyme chains and of the energy donors with which they are linked.

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RECENT ADVANCES IN SCIENCE

ASTRONOMY. By Michael W. Ovenden, B.Sc., F.R.A.S., University Observatories, Cambridge.

Polarisation of the Light of Distant Stars.—1.—The phenomenon of polarisation of light has long been a useful tool in the astronomy of the solar system. The polarisation of the reflected light of the planets has been examined by Lyot. In solar physics, magnetic fields in sunspots are measured by the Zeeman effect as a routine procedure. The general magnetic field of the sun has been · examined in a similar manner (although with inconclusive results), and observations of polarisation of the coronal emissions are of considerable importance. Until recently, however, polarisation has played but an insignificant rôle in stellar astronomy, the only early observations being those of polarisation of starlight by scattering due to particles in the reflection nebulæ. The detection of Zeeman broadening in certain A-type stars by Babcock (see Hunter, Science Progress, 35, 661, 1947) was a first essay into a new field, one that has reaped an abundant harvest for the astronomer and physicist alike. A second venture, the recent discovery by Hiltner and Hall that the light from distant stars is partially polarised, may well rank as one of the most important astrophysical advances of the present era.

2.—The genesis of the discovery lay in a theoretical analysis by Chandrasekhar of the radiation emitted by early-type stars. On examining the consequences of the existing belief that the atmospheres of these stars contain a large number of free electrons, he came to the conclusion that there should be a small proportion of radial polarisation near the limbs. The symmetry of the effect would, however, render it unobservable in the integrated light of the whole disc. Just as Babcock, in his work on stellar magnetic fields, had to use A-type stars whose axis of rotation was in the line of sight, so also had Hall and Hiltner, in attempting the verification of Chandrasekhar's prediction, to make use of a chance orientation with respect to the earth, in this case orientation of the plane of a binary-star orbit. They concluded that such polarisation

should be detectable during the progress of an eclipse of an eclipsing binary, the effect being most marked just before and just after totality.

3.—A first attempt was made by E. M. Janssen at Yerkes in 1946 with the 40-inch refractor (*Astrophys. J.*, **103**, 38, 1946), using a Wollaston prism and photographic photometry. Owing to the experimental error (0·05 mag.) of each determination, and the low percentage polarisation expected, definitive results were not obtained on the star examined, U Sagittæ. The simple photographic technique was modified by Hiltner (*Astrophys. J.*, **106**, 231, 1947) when observing RY Persei, a double singularly suitable for the experiment owing to the early spectral type of the primary (B4) and the deep minimum. A modified Fabry system of photometry was used, an image of the 40-inch objective being focussed on to the photographic plate by a microscope objective. The images so formed allow accurate densitometry. When a Wollaston prism was placed over the microscope objective, the image was split into two components, whose densities could be compared with an error of 0·003 mag. In reducing his results, Hiltner had some difficulty in allowing for a marked instrumental polarisation which changed through the course of a night's observation, but he came to the conclusion that the experiments did indicate slight residual polarisation at the limb of the brighter component, and that the plane of the binary orbit had a position angle of 152°. It is at present uncertain whether these results can be said to confirm the prediction of Chandrasekhar or whether the polarisation is produced outside the star.

Further progress could only be made with more rapid photometric systems which would enable adequate comparisons with other stars to be made. Hiltner and Hall therefore devised photoelectric photometers for use on the 82-inch reflector at McDonald and at the U.S. Naval Observatory. Hiltner's photometer used an analyser in front of the photocell, observations being made at two perpendicular positions of the analyser (*Astrophys. J.*, **109**, 471, 470), while Hall (*Science*, **109**, 166) rapidly rotated an analyser in front of the cell, and measured the AC component of the output. While the latter method allows rapid detection of polarisation, it is not so sensitive as the direct method.

Observations by both instruments were made of the binary CQ Cephei, chosen because of the Wolf-Rayet characteristics of its components, and the fact that its light-curve had been adequately examined. A polarisation of 10 per cent. (some 5 or 6 times the expected polarisation) was detected, but with continued observation

it soon became apparent that the polarisation was independent of the phase of the binary motion. It was not shown by the comparison stars, however, and could not be instrumental. While CQ Cephei is a distant star, the comparison stars used were much closer, and Hiltner (*Science*, **109**, 165) attributed the results with CQ Cephei to an effect introduced by the passage of the starlight through interstellar matter. Subsequent observation confirmed the presence of the effect with distant single stars, as well as eclipsing binaries.

Knowledge of the distances of these stars is obtained from their colour indices by the reddening effect of interstellar matter. Hiltner used the Double Cluster in Perseus, where there is a rapid variation of interstellar reddening with change of galactic latitude, to examine the correlation between degree of polarisation and presence of reddening. From some 15 selected stars of the clusters, he arrived at the conclusion that, while a positive colour excess (i.e. reddening) is a necessary condition for polarisation, it is not a sufficient one. From stars where both polarisation and reddening are present, an approximately linear relation between percentage polarisation and colour excess was found by Hall.

From his first observations Hiltner also found that the nature of the polarisation depended markedly upon galactic latitude. The degree of polarisation was greatest at low galactic latitudes. Furthermore, the plane of polarisation was such that the electric vector was parallel to the galactic plane. Hall, with his more rapid detector, extended these results, and confirmed in a general way the orientation of polarisation. It is strong for stars of low galactic latitude, but is less marked, and may even be non-existent, for stars of high galactic latitude. Deviations also appear in galactic longitude, the orientation being most pronounced about galactic longitude 100° (Hall).

The nature of these results leave little doubt that the polarisation is produced by the preferential scattering or absorption of one polarised component by interstellar particles. In seeking an explanation of the effect, a mechanism must be found which is independent of wavelength, capable of operating over large distances, and shows an association with the structure of the galaxy.

4.—Theories of the polarisation effect are, at the moment, of a very tentative nature, but the postulates made are not unreasonable from an astrophysical standpoint. Spitzer and Tukey (*Science*, **109**, 461, 1949) start from the theory of Oort and van de Hulst (*Bull. Astro. Inst. Netherlands*, X, 187, 1946) on the growth of interstellar smoke particles. These " grains " are supposed to grow by accretion of atoms, and evaporate due to mutual encounters of

clouds. If such a process is operative, particles with diameters larger than the wavelength of light will be practically absent. Most of the elements present in the grains will be chemically bound to the most abundant elements, hydrogen and oxygen. When volatilisation due to collisions occurs, most elements will evaporate as volatile hydrogen compounds, leaving primarily oxides of iron and magnesium. The resulting grain will thus to some extent be ferromagnetic. Laboratory evidence indicates that ferromagnetic particles of 10^{-6} cm. form single domains, and the same is probably true of particles rather larger than this. Such particles would tend to attach themselves end-to-end to form needle-like grains. Assuming that the magnetisation of the interstellar grains is in fact uniform, Spitzer and Tukey find that, for the orientation energy to be of the same order as the thermal energy inside a cloud, magnetic fields of the order of 10^{-5} gauss are needed. It is interesting that fields of just this size were postulated recently by Fermi (*Phys. Rev.*, **75**, 1169, 1949) to explain the origin of cosmic rays. Davis and Greenstein (*Phys. Rev.*, **75**, 1605, 1949) follow rather similar lines of thought, but consider the effect of collisions of grains with interstellar hydrogen. Collisions between grains occur only once in some 10^8 years for each grain, and, while this is sufficiently frequent to allow the evaporation mechanism of Oort and van der Hulst to operate, it is far less frequent than collisions between a grain and a hydrogen atom, which would occur about once a day. In a very short time (from the galactic point of view) the grains would acquire an equipartition energy of 10^{-12} erg for each degree of freedom (rotation or translation), the kinetic temperature of interstellar hydrogen being $10{,}000°$ K. Such rotational energies correspond to angular velocities of 10^9 radians per second, and it is clear that, if orientation of the grains is to provide an explanation of interstellar polarisation, some braking mechanism must operate. They believe that hysteresis is capable of preventing rotation. Fields of the same order as those deduced by Spitzer and Tukey are postulated. From the experimental evidence, using the scattering theory by Gans (*Ann. Physik*, **37**, 881, 1912), it is concluded that an assembly of grains whose axes are in the ratio of $4 : 3$, $\frac{1}{3}$ of the total number being orientated, is consistent with observation.

5.—Until more investigation into the expected constitution of interstellar grains, and their equilibrium in interstellar space, is forthcoming, the above theories must remain speculation, but they do hold out the hope that in the polarisation of starlight we have a means of investigating experimentally a completely new field of astrophysics, the magnetic fields of galaxies. (While it should

not be forgotten that the mechanism of orientation may not be magnetic, this approach appears to be, at the present preliminary stages, the most profitable.) Whatever the nature of the ultimate explanation of the effect, there can be no doubt that astronomers have now in their possession a new and, in spite of difficulties in experimental technique, powerful tool of research into the properties of the rather intangible interstellar clouds, and indirectly for the study of stellar distances and galactic structure in general.

THE HALE TELESCOPE.—1.—On June 3, 1948, at Palomar Observatory, the 200-inch telescope received its dedication. The ceremony was unique in many respects, not the least being the assembly of over 800 guests beneath one observatory dome. In symbolising the approaching culmination of over twenty years of preparation and work in laboratory, drawing office, furnace-room and workshop, it was a fitting occasion in which to announce the naming of the new instrument after one who had made the cause of large telescopes, and the 200-inch in particular, so especially his own, George Ellery Hale.

In a previous article of this series, Dr. Hunter has discussed in general terms the various observational programmes to which the new telescope will be directed (SCIENCE PROGRESS, **36,** 70, 1948). It is proposed here to pay special attention to cosmological problems, in which the Hale telescope will make its greatest contributions to astronomy; such problems have been discussed by Baade (*Publ. Astr. Soc. Pacific,* **60,** 230, 1948).

2.—The first important step will be the extension of the standard magnitude scale to the limit of the new instrument, magnitude $22\frac{1}{2}$. Owing to its unfavourable altitude at Palomar, it is not intended to extend the North Polar Sequence. Instead, a new primary sequence will be set up from selected areas at low declinations. Since it is known from photoelectric work that the N.P.S. forms a uniform magnitude scale conforming to international definition from magnitudes 6 to 16, a few intercomparisons will suffice to determine a common zero for the old and new scales.

While simple in theory, the setting up of an accurate magnitude standard is no light task, as the vast amount of time devoted to the polar standard testifies. The main difficulty lies with the uncertainties of photographic photometry; a single plate has a usable range of only 4 magnitudes. Recent developments of photoelectric photometers using photomultiplier tubes will enable all magnitudes down to $18\frac{1}{2}$ to be measured on a single scale in one step, thus leaving only 4 magnitudes to the photographic process, with which it can cope by a single series of plates.

The new magnitude scale will, of course, be of value in the study of galactic structure, but it will be of profounder significance in extragalactic research. The magnitudes of stars in the near resolvable galaxies will be surely placed on the same scale as the stars of our own galaxy, and in particular an accurate intercomparison of apparent brightness of galactic and extragalactic Cepheids will be available. Since our knowledge of the distances of extragalactic nubulæ rests fundamentally upon the period luminosity law of Cepheids observed in the Magallenic clouds, so will the yard stick of extragalactic distances be more satisfactorily defined. Hitherto, with the 100-inch telescope, the Cepheid variables have been recognised only in galaxies within the relatively small distance of 10^6 light years. Such galaxies form a local cluster, and may well be a poor sample of all galaxies. The range of the new telescope for the detection of Cepheids will be twice this distance, and will include many galaxies outside the local cluster, from which a more truly representative sample may be selected. With the new sample available, the use of the apparent brightness of the brighter stars of more distant galaxies as a means of measuring extragalactic distances (the use of which, with the uncertainties of present observational data, has frequently provoked some not unjustified criticism) will be placed upon a sure footing. Having then available many galaxies whose distances between two and ten million light years are accurately known, an accurate value of the constant of proportionality between red shift and distance can be derived. The absolute value of this constant is of the first importance to theoretical cosmologists. Finally, nebular counts to distances of over 10^9 light years will be possible. Here it is of interest to see whether the general homogeneity of nebular distribution, apparent in the nearer galaxies available to the 100-inch, still holds in a volume of space eight times as large. Indeed, some density gradient has already been suspected by Hubble with the faintest nebulæ at present observed, but photometry down to magnitude 18 with the 100-inch presents difficulties which prevent the results being more reliable than a doubtful suspicion. It may well be within the power of the 200-inch to make a definitive statement on the presence or absence of such a density gradient. The reaction on cosmological theory may be greater even than the reaction of the extension of the red-shift—distance relationship. In Hubble's words " A choice is presented, as once before in the days of Copernicus, between a strangely small, finite universe, and a sensibly infinite universe plus a new principle of nature." The choice may soon be a choice no longer.

3.—The realisation of the above programme will depend, of course, upon the satisfactory performance of the telescope under working conditions, about which nothing was known at the time of Baade's address. The increased light-grasp will be of more importance than the increased theoretical resolution, as atmospheric conditions for realising optimum resolution with large instruments rarely occur.

Hubble has published recently (*Pub. Astr. Soc. Pacific*, **61**, 121, 1949) the first photographs taken with the new telescope. They were taken as routine tests for adjustment, under only average seeing conditions, with a poor aluminium surface, but even in these adverse circumstances nebulæ at least 1½ magnitudes fainter than any reached by the 100-inch have been recorded. While this represents the full gain of light-gathering power corresponding to a doubling of the aperture, even fainter magnitudes will be available under best conditions, owing to an improved sky at Palomar, and the absence of a Newtonian flat.

On the matter of definition, however, results are not so satisfactory, and indicate that the mirror is still not ready for use in the best possible conditions. The trouble lies in a turned-up edge (about 1 fringe high) at the outer 18-inches of the mirror (thus affecting some 30 per cent. of the total aperture area). The presence of this zone was, of course, known from the optical tests in the laboratory, but it was believed that thermal and mechanical effects of the mirror when in operation would counteract it. This has proved not to be the case, and some refiguring is now in process at the Observatory. The main importance of good resolution is to distinguish between stars and nebulæ at the faintest magnitudes accessible. With a short focal ratio ($f/3 \cdot 3$), the coma-free field is only 5 seconds of arc in diameter, but the published photographs illustrate the effectiveness of a subsidiary lens which is used to increase this field (with some loss of light, of course).

The final adjustments of the 100-inch spread over a year and a half. It may well be as long before the Hale telescope begins to make significant contributions to astrophysics. One cannot predict to what extent our present ideas will be confirmed, or how many surprises are in store, but, if the history of the 100-inch telescope is to repeat itself, the new telescope will in the coming decade depict a universe which would appear as strange to us now as our present conceptions will appear naïve then.

PHYSICS. By F. A. VICK, O.B.E., Ph.D., F.Inst.P., The University, Manchester.

DIFFRACTION GRATINGS.—1.—The diffraction grating has been, and still is, one of the most important tools in physics, and it is surprising how few laboratories or firms there are in the world even now capable of producing gratings of the highest quality and resolving power. The theoretical resolving power of a grating, defined by $\lambda/d\lambda$, is nN where n is the order of the diffracted spectrum and N the total number of lines (grooves) in the grating. For a given order and for angle of incidence i and angle of diffraction θ, the resolving power R is given by

$$R = \frac{(\sin i + \sin \theta)Nd}{\lambda} = \frac{(\sin i + \sin \theta)B}{\lambda} \qquad . \qquad . \quad (1)$$

where d is the spacing between the ruled lines and $B = Nd$ is the total breadth of the ruling. The resolving power is thus proportional to the total breadth of the ruling, and the maximum R obtainable theoretically, when $\theta = i = 90°$, is $2B/\lambda$, though in practice the intensity of the diffracted spectrum would in this case approach zero. For $\lambda = 5000$ A.U. and $B = 6$ inches, maximum R is 600,000. The aims in ruling a grating are, therefore (a) to have as great a breadth B as possible, (b) to have N large (so that n may be small), (c) to ensure that the ruling is as uniform as possible, both in spacings and in shape of groove, to avoid the appearance of " ghosts," (d) to throw as much light as possible into the order used, (e) to make the grating as stable as possible, e.g. free from corrosion. There is an urgent need for more good gratings of high resolving power.

2.—In two recent papers (*J. Opt. Soc. America*, **39**, pp. 413 and 522, June and July 1949) Professor G. R. Harrison of the M.I.T. Spectroscopy Laboratory has given a fascinating account of the production of diffraction gratings. The father of the modern diffraction grating was, of course, H. A. Rowland, of Johns Hopkins University, Baltimore. His first ruling engines were capable of producing gratings with $B = 6$ inches, N greater than 100,000 and resolving powers more than 150,000. Many of the gratings still in use in different parts of the world were made on these machines. After Rowland's death in 1901, the machines continued in use until they were damaged by fire in 1904, and they were not properly reconditioned until 1909 when J. A. Anderson began to produce gratings with resolving powers up to 350,000. " After Anderson's departure the Rowland engines languished until 1923, when their operation was taken over by R. W. Wood, who made

many improvements." The machines are still in use, operated by W. Perry and controlled by a "ruling committee" consisting of G. H. Diecke, J. Strong and R. W. Wood. The widest grating which can be produced is 7½ inches, with R approaching 400,000.

In 1900, ·A. A. Michelson and S. W. Stratton constructed in Chicago a machine designed to produce gratings up to 14 inches wide. By 1915 it had ruled 8-inch gratings with R up to 400,000 and one or two trial ones with R as great as 600,000. In 1930 Gale took over the engine and ruled a few 6-inch gratings, but since 1937 the machine has been undergoing rebuilding (at intervals). It is now at M.I.T.

In 1930 Gale, in Chicago, began reconstructing a second machine started by Michelson, which by 1940 had produced a number of good 6-inch gratings. In 1947 it was transferred to the Bausch and Lomb Optical Co., where it is being restored. On leaving Johns Hopkins in 1916, J. A. Anderson went to the Wilson Observatory, and there worked on a large ruling engine previously begun by Jacomini. This has so far produced gratings up to 6 inches in width.

In 1930 Babcock began at Mt. Wilson the construction of a smaller machine, which has produced a small number of plane 7-inch gratings, the best of which has R of 350,000 in the seventh order (69,000 rulings).

These three places, Johns Hopkins, Chicago and Mt. Wilson, are the only sources in the world of gratings of 6-inch and larger widths. A number of smaller engines have been constructed in various places. Professor Harrison lists some of these. Briefly, 2-inch gratings with R up to 60,000 can be produced on several machines in different parts of the world and 4-inch gratings, with R up to 100,000 can be produced on at least five engines. The above account may be sufficient to show how comparatively limited the success has been during the last fifty years. Harrison lists some of the factors which may allow faster progress during the next few decades : (i) the technique of using soft aluminium evaporated on to glass instead of speculum metal, (ii) the improvement in diamond cutters, (iii) improved materials for engine construction, and better methods of lubrication, (iv) electronic and servo devices for enabling the ruling to be controlled by interferometric methods.

3.—To reduce the intensity of the "ghost" lines to 0·1 per cent. of those of the main lines, the ruling should be accurate to one millionth of an inch (or $\lambda/20$). 30,000 lines per inch is normally considered as the closest practical spacing. Groove shapes can be held more constant if there are fewer lines per inch. Most gratings made until recently have been concave, since no large auxiliary lens

is required, but they are more difficult to rule than plane gratings. Concave gratings are seldom ruled with grooves longer than 2 inches, however wide the ruled strip, but plane gratings normally have grooves ½ to ¾ as long as the grating width. A plane grating with suitable lens is thus likely to be faster than a concave one because of the larger ruled area.

4.—The accuracy of ruling is affected by changes in size and shape of the ruling engine parts due to variations in friction, temperature, elasticity and internal strain. The best engines now in use must be operated for 3 to 24 hours before the diamond is lowered into the ruling position, in order that thermal and dynamic equilibrium may be attained. In most engines the grating blank is moved the distance between grooves by a screw driven by a ratchet or wormwheel between strokes of the diamond, but in a machine constructed by Baird Associates the blank is kept moving continuously during ruling. The resulting inclination of the grooves can easily be allowed for by rotating the whole grating slightly in its own plane in the spectrograph. Screws can now be made with good accuracy (e.g. 7×10^{-6} inch in 20 inches after any periodic error has been corrected). About 20–30 threads per inch are used. Warping of parts has been very troublesome : some machines have stood unproductive for years because while each part was being corrected in turn, the others warped ! Harrison gives in his first paper interesting details of the design of the screws and their bearings.

5.—The use of aluminium deposited on glass, already mentioned, has several advantages. There is less scattered light and less wear on the diamond. The blank, at least ⅛ of its diameter in thickness, is stuck on to the ruling carriage by ordinary oil paint, which is slow-drying and does not introduce strains. Some authorities maintain that the diamond should sing while at work, and others that it should remain silent. The groove is pressed rather than cut, and this needs a pressure of several tons per square inch, corresponding to a force of 3 to 5 grams weight. The diamond is adjusted carefully so as to press and burnish the groove in one operation and to give a groove of the correct profile. The flat side of the groove is adjusted in angle for the grating surface to throw the specularly reflected light in the desired direction (the " blaze " direction). According to Babcock, 60 per cent. of the light can be thrown into one order with 15,000 lines per inch, 70 per cent. with 10,000 and 85 per cent. with 2000.

6.—The rooms containing the engines are lined with aluminium foil to assist in radiation control and to lessen dust. The engine itself is provided with a glass or transparent plastic cover thermo-

statically controlled to within 0·01° C. Variable thermal losses through the machine base and floor are eliminated. Most engines operate at from 8 to 20 strokes per minute, so that an average grating can be ruled in 72 hours. Several weeks of diamond adjustment and trial ruling may be necessary beforehand, however. Lubrication problems are not easy. Intermittent oiling during ruling is avoided, since the oil films involved are much thicker than the millionth of an inch tolerance allowed, and the frictional drag should be constant. To test for periodic ruling errors some workers use an interferometric method, obtaining fringes between one plate on the carriage and a parallel one on the guides. Others use a method suggested by Rayleigh in which a trial ruling on glass is cut into two at right angles to the grooves and then the two halves superposed with the corresponding grooves about $\frac{1}{4}$ or $\frac{1}{2}$ the pitch of the screw apart and inclined to each other at an angle of a minute or so. Any periodic error shows up as a periodic pattern when the composite grating is viewed. Sometimes the same effect is obtained by " cross ruling " on the same grating blank. There is no sign that replica gratings will in the near future render unnecessary the continued production of original master gratings.

7.—To obtain the resolving power needed for (*e.g.*) the Zeeman effect and hyperfine structure, concave gratings would be needed having 120,000 to 300,000 lines in 8 to 10 inches width. The radius of curvature would have to be about 35–50 feet, and the spectrograph mounted in a room about 60 feet long. Such a room would be difficult to keep free from mechanical and thermal disturbances. Furthermore, the dispersion obtainable in the second order with a 10-inch grating ruled 30,000 lines per inch, and with a radius of curvature 42 feet, would cover about 60 feet, needing some three dozen photographic plates each 20 inches long to record the spectrum. When the difficulties of constructing and operating such a large spectrograph are added to those of ruling the grating there is every incentive for exploring alternative methods. Professor Harrison goes on to discuss in his second paper gratings having characteristics between the echelon and echelette, but differing from either, and called by him an *echelle* grating. Step-shaped grooves are used, as shown in Fig. 1. Only the steep side, s, is illuminated, at or near normal incidence. The dispersion is $2t/\lambda s$. The grating is a plane one illuminated through a collimating lens. The dispersion of the echelle can be crossed with that of a spectrograph of moderate dispersion, to separate overlapping orders. A typical design of echelle for high resolution in the visible and U.V. would be $s = 0.05$ mm., $N = 1000$, $B = 10$ inches, $R = 1,000,000$ at

5000 A.U. when used with a lens of 250 cm. focal length. This is equivalent to a 10-inch concave grating of the normal type, with radius of curvature 42 feet, 30,000 lines per inch and used in the third order. The dispersion of the echelle is 5 mm. per A.U. at 5000 A.U. The grooves should be such that the side s is flat to within 0·1 of a fringe and not more than 0·1 fringe from its proper
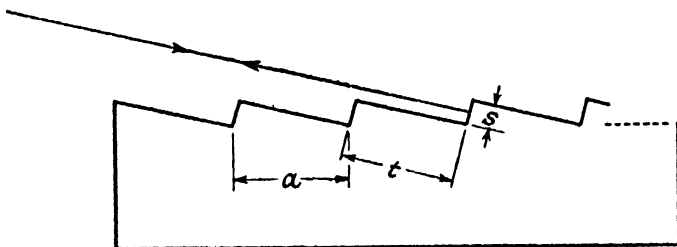
Fig. 1.

position relative to the first groove ruled. Since only about 1000 grooves are required, the ruling should take only a few hours. Also, it should be possible to control the ruling by interferometric means. Professor Harrison is now engaged on preliminary experiments on the production of echelle gratings, and the outcome of these will be awaited with much interest.

8.—In a paper just published (*J. Sci. Instr.*, **26**, 335, October 1949) A. H. C. P. Gillieson considers the advantages over the usual concave grating of a plane grating with a subsidiary concave mirror. The focal curve appears to be flatter and the astigmatism less.

METEOROLOGY. By P. A. SHEPPARD, B.Sc., F.Inst.P., Imperial College of Science and Technology, London.

THE CUMULONIMBUS AND THUNDERSTORM. PART I

1. INTRODUCTION

RESEARCH into the structure of cumulonimbus (abbreviated hereafter to Cb) and into the most active of its forms, the thundercloud, has been prosecuted with some vigour in England and Germany since the early 30's, while latterly a very large effort has been expended on the subject in the United States and important work continues elsewhere. In the present article we shall examine the picture which begins to emerge, first in regard to the circulation and thermodynamics of the Cb, and then in Part II in regard to its

electrification. From neither aspect is the picture anything like complete but substantial headway has been made.

It seems appropriate to state at the outset the broad lines along which the problem has been tackled. Simpson (1937, 1941) with his collaborators, Scrase and Robinson, opened a new era of direct investigation, in the now quite well-known series of free-balloon flights into Cb from Kew Observatory, using the alti-electrograph. The direct approach was also taken up in Germany, but there mainly by sailplane and to some extent by aircraft, and was supplemented by laboratory investigations under Findeisen on the microphysics of clouds and their electrification. Then, in 1946 and 1947, a very large programme of exploratory aircraft flights into Cb was undertaken in the United States, first in Florida and later in Ohio, and important results have been described by Byers and Braham (1948). Moreover, during the period under review an entirely new instrument of research into Cb has emerged in centimetric radar, which is an exceedingly sensitive device for detecting the onset of precipitation in the cloud and for studying certain of its characteristics. On the electrical side the delineation of the wave form of the atmospheric (Wichmann, 1941–43), following pioneer work by Appleton and Chapman (1937), is supplementing knowledge gained by Schonland and his collaborators in the continuing work on the lightning flash by means of the Boys camera. This aspect of thunderstorm electricity has been fully reviewed by Meek and Perry (1946).

These experimental investigations have naturally been accompanied by new theoretical work on the problem and Normand's (1946) thermodynamic analysis is outstanding. Dynamical investigations have not achieved any notable success as yet but the problem is difficult, while in theories of the electrical phenomena Frenkel's work (1944, 1946, 1947) only, deriving from the contact potential of water and ice, carries strong conviction.

2. STRUCTURE AND CIRCULATION

The life-cycle and structure of the Cb which emerge from the observational work of the last decade or so, particularly from the investigations in the United States as reported and discussed by Byers and his collaborators, are of the following sort. A Cb consists of one or more convective systems or " cells," each of which passes through a characteristic cycle of growth, maturity and decay lasting an hour or two, and to be described in more detail immediately. From—generally—an initial cell others appear to be born, so that the cloud is a self-propagating system consisting of up to four or five cells in various stages of development or decay at any

one time during the life of the complete system. Each cell has a diameter of from 1 to 8 km., and there is a space of cloud-filled air of about 1 km. between the component cells.

The individual cell is initially a growing cumulus (Cu), which itself may occasionally result from the coalescence of two or three smaller Cu. Vertical growth is normally rapid with updraughts, several hundred metres in horizontal extent, increasing in magnitude from below the cloud base to upwards of 30 m. sec.$^{-1}$ on occasion in the upper portions (see Wichmann, 1949). These updraughts appear to have much in common with the jets studied in aerodynamic laboratories (see e.g. Goldstein 1938), though the static instability to which they are due and the effects of condensation and release of latent heat are complicating factors. In this stage the Cu may tower considerably above the 0° C. level, but the cloud is probably composed almost exclusively of water droplets, strongly supercooled in the upper levels, and colloidally stable so that no precipitation occurs. Measurements of the horizontal flow pattern around the developing Cu by means of simultaneous balloon soundings show (Byers and Hull, 1949) that horizontal convergence of air, of order 2 per cent. per minute over areas 5 to 8 km. in diameter, occurs *at all levels* up to the top of the cloud. Fig. 1a shows the essential features of the growing single cell.

The Cu stage ends and the mature stage begins with the appearance of slight glaciation in the upper reaches of the cell, quickly followed by the formation of precipitation elements, large ice crystals, graupel and hail, arising from the colloidal instability of ice and supercooled water and from agglomeration of cloud droplets with the larger solid elements. This precipitation, which occurs first in a limited region, horizontally and vertically, of the cloud (initial radar echoes centre on about the − 10° C. level—see Workman and Reynolds, 1949), appears to trigger a substantial downcurrent of air, up to about 13 m. sec.$^{-1}$, in its neighbourhood, and, as we shall see below, adds substantially to the amount of energy liberated by the convection process. Consistent with its association with precipitation, the downcurrent is found only in the middle and lower reaches of the cloud, continuing from below the cloud base towards the ground, over which it spreads to provide the characteristic squall line, and bringing with it a substantial drop in temperature due to the heat given up by it in the partial evaporation of the precipitation and cloud. A substantial updraught continues meanwhile in other parts of the cell at low and middle levels and in all portions at the highest levels. Balloon flights at this stage of the storm show that convergence gives place to roughly equal
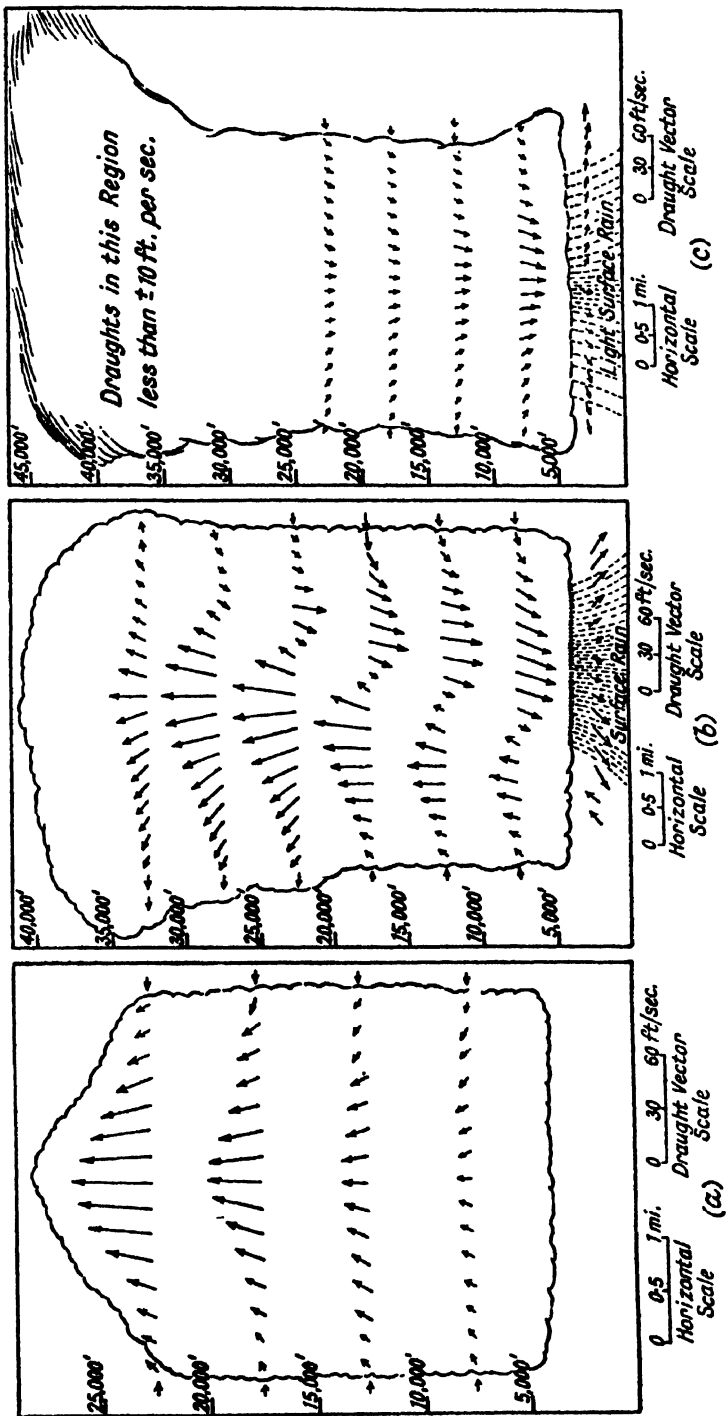
FIG. 1.—Circulation within single cell of Cumulonimbus in (a) Cu (growth) stage, (b) mature (heavy rain) stage, (c) decay (anvil) stage.

(From BYERS and BRAHAM, 1948.)

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divergence in the bottom km. or so of the cell, while the convergence at higher levels intensifies to about 5 per cent. per minute. Moreover the outspreading cold air of the low-level divergence appears to provide the trigger for the initiation of new cells. For the Florida storms investigated by Byers there is a practically linear relation between the magnitude of the maximum surface divergence over areas of order 10^2 km.^{2} and the maximum rate of rainfall.

According to Workman and Reynolds, who for simplicity discuss observations on single cell Cb only, the first appearance of precipitation beneath the cloud base, generally some ten minutes after the first appearance of a radar echo from within the cloud, synchronises roughly with the first lightning flash of a Cb producing thunder. This initial flash is internal to the cloud and only some five minutes later does the first cloud-to-ground discharge occur. Meanwhile the top of the radar echo, which at first moves steadily upwards to about the $-30°$ C. level, now moves downward with the occurrence of precipitation from the cloud base. Fig. 1b epitomises the structure in the mature stage of the cell.

The third stage (Fig. 1c) is one of decay and arrives when the downward motion, the dynamical characteristic of the mature stage, extends, though much diminished in magnitude, to the whole of the cell except the topmost portion, where weakened upward motion persists for some while and where there is rapid growth of the cirrus anvil. The rain diminishes much in intensity and ultimately the cloud of that particular cell dissipates from below. Remnants of the cloud may persist in stratified form at higher levels.

Some caution must be exercised in the application of the above picture. Thus it refers mainly to the so-called " heat " thunderstorm of marked diurnal variation, and the heights and velocities given in Fig. 1 are appropriate to such storms in Florida. Frontal thunderstorms, particularly those of winter, may exhibit some differences in character, related, for example, to the observation that summer storms often produce hailstones, whereas winter storms more characteristically and regularly produce soft hail.

3. MICROPHYSICAL FACTORS

We shall not attempt here to deal in detail with the microphysics of Cb, but choose one or two aspects as illustrative of the sort of problem involved. We reserve to a later section the electrical phenomena involved.

It is abundantly clear from the work of Simpson, Findeisen and later researchers that the properties of ice crystals, either in admix-

ture with the vapour phase only or with liquid water also, determine much of the behaviour of Cb. Thus the efficiency of ice-forming nuclei at temperatures above − 32° C. decreases with increase in the rate of ascent of the air, so that the temperature at which glaciation first occurs is probably lower and the cloud-top must reach much higher in intense summer storms than in less violent winter storms. Again Findeisen (1940, 1942) has shown that ice crystals, either when growing or evaporating, may produce quite large numbers of small ice splinters (size of order 10^{-3} cm.). If this occurs in clouds then the apparent rarity of ice-forming nuclei in clear air, or in air containing supercooled water droplets at temperatures above − 41° C., or at any rate above − 32° C. (see SCIENCE PROGRESS, No. 139, July 1947), is effectively made good once a few ice-forming nuclei have become effective at these higher temperatures, for a chain reaction then ensues. Certainly the glaciation of a Cb, once it occurs, proceeds with great rapidity and is apparently responsible both for the initiation of the precipitation process and equally for the quite rapid seeding and consequent decay of a cell.

The growth of precipitation elements in Cb poses many problems which are only partially resolved. (These problems, oddly enough, have much in common with the problems of aircraft icing.) One of the most fascinating and, as appears, most fundamental in Cb microphysics is the production of hailstones. The older, and never clearly expounded, theory of a stone making several vertical traverses of a Cb before final emergence of the layered structure from the cloud, would appear to be giving place to a more satisfying explanation as quantitatively discussed by Schumann (1938) and Ludlam (1950). Given a precipitation element, such as an ice crystal or graupel, of sufficient size to fall with appreciable velocity relative to the surrounding cloud droplets, accretion of droplets will occur at a rate depending on the relative velocity, on the liquid water content in the region and on the size of the droplets (the smaller tend to get swept round the precipitation element by the airflow round the latter). The heat economy of the element is then determined by the transfer of sensible heat to the environment, the heat taken up in evaporation from the surface and the heat realised by fusion of the impacting cloud droplets. If the heat loss by the first two processes can keep pace with the third the cloud droplets will freeze on impact with the precipitation element and rime (ice with occluded air) will result. If however the rate of fall, water content and efficiency of catch are sufficiently large—as Ludlam shows may readily be the case—the latent heat of fusion will not be disposed of without a substantial rise in the temperature of the

element, the surface of the hailstone will remain wet at near 0° C., and clear ice (glaze) will form beneath. The substantial variations in the three controlling factors at different levels in the cloud make a layered structure the likely outcome.

Modern radar technique has not only aided much in the elucidation of the cell structure outlined in Section 2 above, but promises to provide much additional knowledge of processes in Cb. The echo intensity at a particular wave-length λ depends on two main factors (Ryde, 1946), the dielectric constant of the reflecting particles, water, or ice, or water and ice in association, and $\Sigma(nd^6)$ where n is the number of particles of diameter d, and increases with $1/\lambda^4$. A slight complication is introduced by the attenuation of the radar beam by precipitation, increasing with decrease in λ. The scope of this method of exploration is apparent, particularly if a cloud is examined on two or more wave-lengths. But there is insufficient space to pursue it here and the reader may be referred to a summary by Sheppard (1941) or to original papers by Marshall *et alii* (1947) and Wexler (1947*a*, *b*, 1948).

4. THERMODYNAMICAL AND DYNAMICAL CONSIDERATIONS

A recent most important thermodynamic discussion of convection is due to Normand (1946) and we cannot hope to do justice to it in the present summary. He first insists on the overriding importance of total heat, or enthalpy, H, of a system in determining stability. The total heat of a column or system of dry air is compounded of its potential (P) and internal (E) energy, the subdivision being, in the usual nomenclature, $P : E : H = R : c_v : c_p = 2 : 5 : 7$. Thus, to say, as is not infrequent, that a system develops kinetic energy out of a re-arrangement (diminution) of its potential energy is a half truth and misleading. He proceeds to show that the statement of the first law $Q = dH + dK$, where Q is the heat added and dK is the increment of kinetic energy, may be quite adequately approximated, for systems producing Cb, by $dH + dK = 0$, since a positive Q is neither necessary for the production of kinetic energy nor is its actual magnitude, *e.g.* from solar diurnal heating of the lower atmosphere via the ground, comparable with the energy released in Cb or other systems—a result due originally to Margules.

Normand considers a number of cases of the re-arrangement of the total heat (or heat-drop) of an unstable system leading to a minimum H, the stable end-product, from which we select an illuminating example of the *irreversible* transformation of a dry atmosphere with superadiabatic lapse rate. Irreversibility provides for mixing between the portions of air comprising the system, as happens

in reality, while generalisation to an atmosphere containing water vapour with condensation introduces no essential modification of the argument. Let the initial lapse rate in the system (Fig. 2)
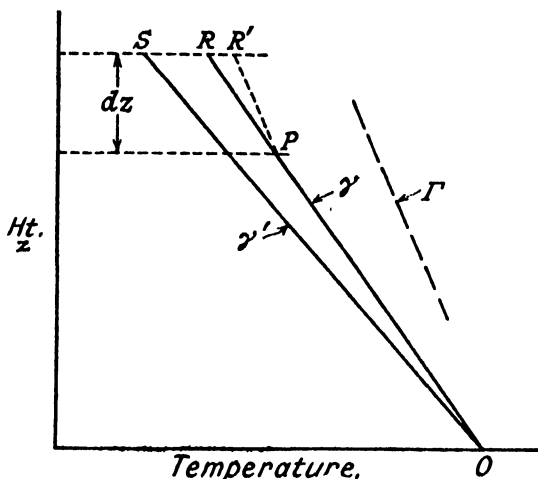
FIG. 2.—Temperature–height diagram for irreversible overturning with mixing. Initial lapse rate of system (γ') = OS, path curve (γ) = OPR, dry-adiabatic lapse rate (Γ) = PR'.

be γ', the dry-adiabatic lapse rate be Γ ($< \gamma'$), and let the rising air of the system follow a lapse rate (path curve) γ intermediate between γ' and Γ on account of mixing with its environment. We take γ' and γ to be constant in the layer involved in readjustment and suppose the rising air starts as an infinitesimal mass from the ground ($z = 0$), increasing to mass m at the height z on account of
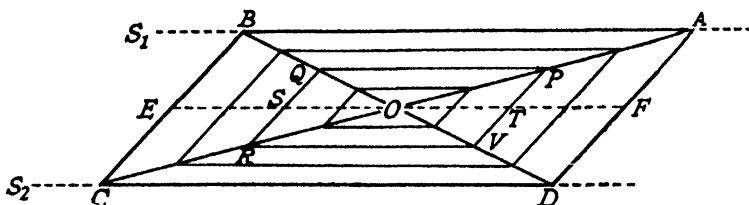
FIG. 3.—Temperature–entropy diagram, with temperature increasing to the right and entropy increasing upwards, for a system with initial superadiabatic lapse rate AC.

(*From* NORMAND, 1946.)

mixing. This mass m is represented by P in Fig. 2. If it rose dz from P without further mixing it would traverse a dry-adiabatic PR', whereas it acquires additional mass dm and traverses PR. We have

$$dm/m = \mathrm{RR'}/\mathrm{SR} = (\gamma - \Gamma)dz/(\gamma' - \gamma)z.$$

Hence $dm/m = \mu \, dz/z$ where $\mu = (\gamma - \Gamma)(\gamma' - \gamma)$, and integrating, $m = \text{const.} z^\mu$. When $\mu = 0$ there is no mixing and the process is reversible. The upper limit of μ is set by the condition that the final result of overturning must not be an unstable lapse rate, and we shall see that this is given by $\mu = 1$ $(m = cz)$ for which $\gamma = (\Gamma + \gamma')/2$, with the final lapse rate *in the system* equal to Γ. For, in the entropy-temperature diagram of Fig. 3, let APORC represent the initial condition of the system, with AB, CD isentropics (lines of lapse rate Γ) and AD, BC isobars. Then when $\gamma = (\Gamma + \gamma')/2$, air rising from A will finish at the mid-point E of BC and air moving down from C under similar conditions of mixing will finish at F ; air from P will finish at S and from R at T ; and so on. The final lapse rate in the system is then given by FE, *i.e.* Γ, and the amount of energy released in the irreversible transformation is given by considering any process which will provide this final lapse rate provided no contradiction with the essential assumptions is involved. Thus unit mass may be taken to move adiabatically from A to B and there mix with unit of mass at C to provide two units at E. Simultaneously unit mass may descend from C to D and there mix with unit mass at A to provide two units at F. The heat-drop or energy freed in the process is given by the area ABCD and this is shared among four units of mass. The whole system may be so transformed to the final condition, taking 4 units of air at a time from corresponding levels, *e.g.* from P and R, where the pressure difference (mass per unit horizontal area) between A and P is equal to that between C and R, and the heat-drop is given by PQRV. Then the heat-drop for the whole system is given by the volume of a pyramid on base ABCD and of height equal to M/4 where M is the total mass of the system. The average change in H per unit mass is then (ABCD)/12, and this is the *minimum* that may occur, since the final lapse rate is dry adiabatic and a less stable end result is not possible. It is readily enough seen that this is half the *maximum* which, arising from a reversible adiabatic process, would give a final lapse rate DB and only two units of mass would be involved in each " parallelogram " of energy liberated. Thus, whatever the degree of mixing (or entrainment of air, as it has come to be called in American literature), the energy realisable lies between rather close limits. It is very important to realise that in either of the cases examined half the energy realised comes from the descending air ; the energy of ascending air is often emphasised to the exclusion of the other.

The problem of the *saturated* unstable column is complicated by the uncertainty of the conditions of descent, but if the latter takes

place at saturation the methods used above for the evaluation of the energy realised are the same, provided saturated adiabatics replace the dry so as to allow for the total heat of the water vapour. The descending air will then again make its own substantial contribution to the heat-drop. If, however, the descent is dry the heat drop is reduced by at least a half of the maximum attainable with saturated descent from the same initial system. Bjerknes (1938) considered a system with lapse rate between the dry and saturated adiabatic in which the descent was unsaturated and showed, in the present nomenclature, that there would be no heat-drop unless the ratio of the area of cloud to clear air was less than a certain critical value determined by the initial lapse. While accepting the reality of some dry descent in the convection process, Normand stresses the necessity for appreciable saturated descent also. He says we must " keep in mind the possibility that Cb is a cloud that takes advantage of the energy available from moist descending currents, that it is organised to take in potentially cold air at the higher levels as well as potentially warm air at the lower ; and, though the moist fraction of the descending air has not the same mass as the whole up-current, it is an active participant in the kinetic energy of the storm and not just a drag on the available energy." These ideas have received almost complete confirmation from the more recent works of Byers and his colleagues presented in Section 2.

Other workers have recently tackled the problem discussed above of the effects of mixing in Cu and Cb formation, among whom may be noted Stommel (1947) and Austin and Fleisher (1948). Stommel deduces large mixing fractions in the rather shallow Cu clouds of the trade wind region, using simultaneous soundings of pressure and humidity within and outside the clouds, but there is perhaps some doubt whether the observations upon which his figures are based have sufficient validity. He infers a liquid water content increasing with height from the cloud base and falling off rather rapidly in most cases near the top. Austin and Fleisher make similar computations, based on assumed lapse rates, taken to be the same inside and outside the cloud, for different humidities in the environment. The computed entrainments and water contents are not dissimilar from Stommel's. Byers and Braham infer entrainment values of up to 100 per cent. in 200 mb of ascent from aircraft lift and convergence figures and consider the lapse rate in the large growing Cu cloud to approximate quite closely to that of the environment.

Sawyer (1949) has examined some of the consequences of evaporation in the saturated descent of air in Cb. He explains quantita-

tively the pressure rise at the surface during frontal storms, from incompletely compensated convergence aloft following the vertical shrinking of the air cooled by evaporation beneath. He considers too that the deflection of the cooled downflow by topographical features may well determine the paths of convective systems once initiated.

<div align="center">(To be concluded)</div>

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GENERAL AND PHYSICAL CHEMISTRY. By J. W. SMITH, D.Sc., Ph.D., F.R.I.C., Bedford College, London.

BOND ENERGY AND THE FACTORS CONTROLLING IT.—The strength of chemical bonds is a problem of interest to all chemists. The recent approaches to this problem, particularly with regard to the correlation of the bond energy with the fundamental character of the bond and of the atoms or groups concerned in it, comprise, therefore, one of the most important developments in the subject. This summary is based principally on the views of Walsh, who has done much to clear up the many anomalies which have long been perplexing, and to place the subject on a rational basis.

The nomenclature has in the past been somewhat confused, but Walsh (*J. Chem. Soc.*, 1948, 398) emphasises that bond energy should be taken as an energy value which is a simple measure of the strength of a bond as it exists in the molecule, and must be distinguished from the dissociation energy, which is the difference between the energy of the molecule and the energy of the two fragments into which it would be split by rupture of the bond. The bond energy should bear a relation to the bond length, *i.e.* the equilibrium distance between the two nuclei concerned in the bond, and the force constant, *i.e.* the restoring force which acts on the system when the nuclei are displaced from their equilibrium positions.

Although for diatomic molecules the dissociation energy is approximately equal to the bond energy, for a bond in polyatomic molecules it often differs considerably from the bond energy owing to the circumstance that rupture of one bond causes the strengths of the remaining bonds to alter. For instance, the internuclear distance and force constant indicate that the O—H bond is stronger in the H_2O molecule than in the OH radical; the bond energy in H_2O is 110 kcals. per mole, whereas the dissociation energy of the H_2O molecule to give H and OH is 118 kcals. per mole and that of the OH radical to give H and O atoms is 100 kcals. per mole. This difference arises through the fact that when one of the bonds in the H_2O molecule is broken energy is absorbed by the remaining bond, which therefore becomes weaker. Much confusion has arisen through the fact that the term "bond strength" has frequently been used almost synonymously with dissociation energy. It is best, however, to retain this term as a qualitative description of the property of the bond which is expressed quantitatively by the bond energy.

From the simple example discussed it is evident, therefore, that it is incorrect to identify the bond energy with the dissociation energy, as was at one time assumed, because, the two bonds of the H_2O

molecule being identical, their energies must be equal. It follows, too, that the energy of a bond between two specified atoms differs for different molecular species, and that it is impossible to state, without qualification, that the bond energy of, say, the O—H bond is 110 kcals. per mole. Its value will depend on the other bonds present in the molecule. Values of such bond energies may conveniently be written in the form $E(OH)_{H_2O} = 110$ kcals. per mole.

When a molecule is of the form XY_n, comprising a central atom of one species surrounded by similar atoms of a second species, so that only one type of bond is present, the energy of each bond can be taken as Q_a/n, where Q_a is the heat liberated when the atoms, in the valence states in which they exist in the molecule, combine to form the molecule. For instance, the heat of formation of gaseous water from hydrogen and oxygen gases is 57·8 kcals. per mole, whilst the heats of dissociation into atoms of H_2 and O_2 are 103·4 and 118·2 kcals. per mole, respectively. Hence the heat of the reaction $2H + O \rightarrow H_2O$ $(= Q_a)$ is $103\cdot4 + 118\cdot2/2 + 57\cdot8 = 220\cdot3$ kcals. per mole, and hence $E(OH)_{H_2O} = 110\cdot1$ kcals. per mole.

In the case of polyatomic molecules, however, one cannot strictly isolate bonds completely from one another. Although most of the energy liberated in forming the compounds is due to the overlap of electron clouds in forming the bonds, a little is due to overlap other than in these bonds. For instance, in the CCl_4 molecule interaction between the chlorine atoms is important and must affect the force constant and the ionisation potential. In the case of such compounds as methane, however, the approximation introduced by referring these quantities to a particular bond is not serious and is completely outweighed by the usefulness of the conception.

When more than one type of bond occurs in the molecule the calculation of their energy values requires some assumptions. For instance, the heat of formation of gaseous H_2O_2 from the elements in the standard state is 33·6 kcals. per mole. By adding to this 103·4 and 118·2 kcals. per mole, the heats of dissociation into atoms of H_2 and O_2 molecules respectively, it follows that $Q_a = 255\cdot2$ kcals. per mole. This must equal the sum of the bond energies of all the bonds present in the molecule. On the assumption that the O—H bond energy in H_2O_2 was the same as in water, Pauling (*Nature of the Chemical Bond*, 1940) deduced that the O—O bond energy was 34·9 kcals. per mole. Bond length and force constant data, however, indicate that the O—H bond in H_2O_2 is slightly weaker than that in the OH radical, which, in turn, is weaker than the O—H bond in H_2O. Walsh (*J. Chem. Soc.*, 1948, 331) suggests that 96 kcals. per

mole is a more probable figure, and hence deduces that $E(OO)_{H_2O}$, must be about 64 kcals. per mole. This value is consistent with the energies of other bonds which would be expected to be of similar strength.

The parallelism between the bond energies deduced in this way and the force constants (k) derived from spectroscopic data is illustrated by the values for the linkages of the type H—X shown in Table I.

TABLE I

BOND ENERGIES AND FORCE CONSTANTS

Linkage.	$(HC)_{CH\ rad.}$	$(HN)_{NH_3}$	$(HO)_{H_2O}$.	$(HF)_{HF}$.
E (kcals per mole) . .	80	93	110	148
k (dynes per cm) . .	$4·09 \times 10^5$	$6·5 \times 10^5$	$7·66 \times 10^5$	$9·62 \times 10^5$

The next question which arises is what factors determine the energy and consequently the strength of any particular bond ? The earlier theories and the more recent views of Pauling, of Polanyi and his co-workers, and of many others have now been revised, combined, and very considerably extended by Walsh (*Trans. Faraday Soc.*, 1947, **43**, 60 ; *J. Chem. Soc.*, 1948, 398) so that a fairly clear picture is now presented.

Walsh enumerates the factors influencing the strengths of bonds as being the electronegativity of the bonded groups, bond polarity, overlap of atomic orbitals, and repulsion of filled atomic orbitals. These factors will be discussed successively.

Firstly, as the binding of electrons in a molecular orbital is related to that in the atomic orbitals from which the molecular orbital is derived, bond strengths would be expected to increase with increase in the electronegativity of the bonded atoms. Electronegativity can be regarded as the power of an atom in a molecule to attract electrons to itself, and this concept was put on a quantitative basis by Pauling (*J. Amer. Chem. Soc.*, 1932, **54**, 3570) through the following argument. If it be assumed that the bonds between like atoms can be regarded as of purely covalent type, then the bond energy of a pure covalent bond A—B would be the arithmetic mean of the bond energies of A—A and B—B. Any difference (Δ) between the energy of this bond and this arithmetic mean would be due to the additional ionic character of the bond and hence closely related to the difference between the electronegativities of the atoms concerned. He found that these Δ values did not obey an additivity relationship, but that their square roots did so, and the values of $0·208\ \sqrt{\Delta}$, *i.e.* the square root of the energy values expressed in electron-volts, were taken as

a measure of the difference between the electronegativities of the atoms. From such data the values shown in Table II were assigned to the electronegativities of some common elements.

TABLE II

ELECTRONEGATIVITY VALUES (*Pauling*)

H	2·1	C	2·5	N	3·0	O	3·5	F	4·0
		Si	1·8	P	2·1	S	2·5	Cl	3·0
		Ge	1·8	As	2·0	Se	2·4	Br	2·8
								I	2·5

This approach has been followed up by several workers, particularly Gordy (*J. Chem. Phys.*, 1946, **14**, 305), who devised an empirical relationship between bond strength and the product of the electronegativities of the bonded groups. Although this relationship showed satisfactory accord with the available data in a number of cases, there were some outstanding exceptions, notably hydrogen peroxide and fluorine. This will be shown later to arise from the fact that electronegativity is an important factor in determining bond strength, but not the only one.

That there is a general relationship, however, is shown by comparing the electronegativity values shown in Table II with the bond energies for linkages of the type H—X in Table I and for linkages of the type X—X in Table III. In each of the groups of the

TABLE III

BOND ENERGIES OF X—X BONDS

Bond . . . . . E (kcals per mole) .	$(C—C)_{C_2H_6}$ 96	$(N—N)_{N_2H_4}$ 64	$(O—O)_{H_2O_2}$ 64	$(F—F)_{F_2}$ 64
Bond . . . . . E (kcals per mole) .	$(Si—Si)_{Si_2H_6}$ 51	$(P—P)_{P_4}$ 44	$(S—S)_{S_8}$ 54	$(Cl—Cl)_{Cl_2}$ 58
Bond . . . . . E (kcals. per mole) .	$(Ge—Ge)_{Ge_2H_6}$ 34	$(As—As)_{As_4}$ 34	$(Se—Se)_{Se_6}$ 41	$(Br—Br)_{Br_2}$ 46
Bond . . . . E (kcals per mole) .				$(I—I)_{I_2}$ 36

periodic table the electronegativity and bond energy of the X—X bond each decrease with increasing atomic number, although the difference between the bond energies of the fluorine and chlorine molecules is less than would be anticipated from the great difference between their electronegativities. On the other hand, the fact that the bond energies of N—N, O—O, and F—F linkages are almost equal, and the bond energy of the C—C bond 50 per cent. greater than these, is quite contrary to the electronegativity theory.

For the particular case of carbon, Walsh has pointed out the special importance of the effect of hybridisation of the s and p orbitals on electronegativity. It has been shown by Coulson that the average value of the position of the electron is further from the nucleus for the $2p$ than for the $2s$ orbital, so a carbon atom will have greater electronegativity when exerting a $2s$ than when exerting a $2p$ valency ; thus the $2p$ electrons are less strongly bound than are the $2s$ electrons. The important consequence of this, Walsh has shown, is that in a hybrid valency the atom will have the greater negativity the greater the proportion of s character in the valency. One would anticipate, therefore, a progressive increase in the electronegativity of the carbon atom, and consequently in the strength of the C—H bond, on passing from the CH radical, where the valency is of a pure p type, through methane, with tetrahedral sp^3 hybridisation, and ethylene, with trigonal sp^2 hybridisation, to acetylene, where the σ bond has the digonal sp hybridisation. This change is reflected in the progressive increase in the force constants of the C—H bond, the decrease in the bond length, and an increase in the bond energy (Table IV).

<div align="center">TABLE IV</div>

Molecule.	k(C—H) (dynes per cm.)	r(C—H) (A.)	E(C—H) kcals. per mole
CH radical	$4 \cdot 09 \times 10^5$	$1 \cdot 120$	80
CH_4 . .	$4 \cdot 97 \times 10^5$	$1 \cdot 094$	104
C_2H_4 . .	$5 \cdot 1 \times 10^5$	$1 \cdot 087$	106
C_2H_2 . .	$5 \cdot 85 \times 10^5$	$1 \cdot 059$	121

From the viewpoint of ordinary chemistry, the theory is supported by the acidity of acetylene and by the fact that propiolic acid is a stronger acid than acrylic acid. Further, the studies of Braude and Jones (*J. Chem. Soc.*, 1946, 128) of the relative reaction velocities in processes requiring electron accession at the reaction centre showed that vinyl carbinols undergo acid-catalysed isomerisation with rate constants 200–12,000 times the values for the corresponding acetylenyl carbinols, thereby showing that the acetylenic carbon atom has a greater electron-attracting power than the ethylenic one. This difference in electron attracting power was recognised by Braude and Jones, but explained by them from a rather different point of view to that discussed here.

The effect of the state of hybridisation on the electronegativity of the carbon atom suggests that the greater strength of the bonds between a vinyl or phenyl group and, say, a halogen atom is not due entirely to resonance involving the lone-pair electrons of the halogen

atom. It also accounts for the fact that the bond energy of the C—C bond in ethane is much greater than that of the N—N bond in hydrazine.

Another consequence of the theory is that for compounds of the type CH_2X—CH_2X, where X is an atom or group of greater electronegativity than hydrogen, the bond strength of the C—C bond should be increased, because, having so to speak been partially denuded of the electrons shared with the group X, the carbon atoms tend to hold the more firmly to the electrons held between them. There is a large amount of evidence in favour of this ; for instance Bateman and Jeffrey (*Nature*, 1943, **152**, 446) have shown that the bond between the central carbon atoms in compounds of the structure C=C—C—C—C=C is appreciably shorter than that in ethane.

Thus the electronegativity of the atoms concerned has a profound effect on the bond strength, but the anomalies show that it cannot be the sole factor which operates. Coulson (*Proc. Roy. Soc.*, 1939, **A169**, 413) has shown that the linear combination of atomic orbital approximation of the molecular orbital theory predicts that for a given bond the bond strength decreases with polarity. However, although Skinner and Sutton (*Trans. Faraday Soc.*, 1944, **40**, 164) emphasised the importance of this factor in determining the bond-lengths of the halogen derivatives of tin, arsenic, and nitrogen, it was generally neglected until its importance was stressed by Walsh (*ibid.*, 1947, **43**, 60).

In the absence of any polarity effect it would be anticipated that replacement of one hydrogen atom in ethane by a hydroxyl group would increase the strength of the C—C bond, owing to an increase in the electronegativity of the carbon atom which becomes linked to the hydroxyl group. Actually this bond strength is less in ethyl alcohol than in ethane, an effect which may be attributed to the polarity introduced into the bond. Similarly in spite of the central carbon atom in keten CH_2=C=O having a digonally hybridised configuration, the C—C bond, being polarised, is no stronger than that in ethylene, whereas in carbon suboxide O=C=C=C=O the reduced polarity of the C—C bonds and the increased electronegativity of the carbon atoms linked to the oxygen atoms cause these bonds to be stronger than that in ethylene.

Extreme examples of this effect would be anticipated in cases where a co-ordinate linkage is formed. Thus, when dimethyl ether forms a complex with boron trifluoride $(CH_3)_2O \rightarrow BF_3$, the donation of one of the lone pairs of electrons of the oxygen atom to complete the octet of the boron atom should have the effect of increasing the electronegativity of the oxygen atom towards the

electrons of the C—O bond. This bond, however, is actually weakened as a result of its increased polarity. The fact that the B—F bonds are also lengthened and weakened is attributed partly to the increase of the initial $\overset{+}{B}$—$\overset{-}{F}$ polarity and partly through the change of the boron valencies from trigonal to tetrahedral.

Again, the bond polarities in the NH_4^+ and H_3O^+ ions cause the N—H and O—H bonds in these ions to be weaker than in ammonia and in water respectively.

These facts raise an important question regarding the nature of these polarised bonds. It has become common to describe them as involving resonance between a " normal " covalent bond and a " normal " ionic bond. For such cases there is usually ascribed to the bond a resonance energy, but this is based on the assumption that the bond energy is higher in the intermediate state than in either of the extreme states, which is contrary to observation. Walsh suggests that, as the internuclear distance in the purely ionic structure is appreciably greater than in the purely covalent structure, one of the essential conditions for resonance is absent ; only if the resonance energy were sufficient to stretch the purely covalent bond and to compress the purely ionic bond to its actual length could resonance between the two forms occur in a particular bond.

Yet another factor which must be taken into account, however, is the principle of maximum overlap, i.e. that, other things being equal, the greater the overlap of atomic wave functions the greater the strength of the resulting molecular orbital. Thus, for instance, the " sideways " overlap of the $p\pi$ bonds is less than the endwise overlap of the $p\sigma$ bonds, and hence the π bonds in double and triple bonds are weaker than the σ bonds. This question of orbital overlap leads to a limit in the increase of bond strength with increasing electronegativity of the atoms. Thus, on passing from nitrogen and oxygen to fluorine, that is, as the electronegativity of the atoms increases, the $2p$ electron distributions will contract inwards towards the nucleus until a point is reached where, in order to secure appreciable overlap of the atomic wave functions, the nuclei must be so close that appreciable repulsion between them results. Therefore, beyond a certain point, increase of electronegativity may weaken rather than strengthen the bond.

This rather surprising conclusion receives strong support from the variation of the O—O bond strength in peroxides ; the greater the transfer of negative charge to the oxygen atoms the greater is the bond strength. This must mean that the electronegativity of the oxygen atoms is too great to give an overlap corresponding to the maximum bond strength, and that reduction of their electro-

negativity increases the overlap, strengthening the bond. Consequently it is not surprising that Gordy's relationship failed for the O—O bond in hydrogen peroxide.

It has been pointed out that fluorine has only a slightly greater bond energy than chlorine, in spite of the much greater electronegativity of the fluorine atoms. Walsh's suggestion that the F—F bond strength is diminished by the reduced overlap is supported by the fact that in ClF the bond strength is much greater (86·5 kcals. per mole), although a polarity effect is introduced and the electronegativity product reduced. This increased bond energy was attributed by Pauling to the resonance energy arising from the more ionic character of ClF, but, as has been mentioned, this is contrary to the usual effect of polarity in the bond and, in any case, such an effect would be scarcely expected to have the large effect here observed.

That the N—N bond in hydrazine is weaker than the C—C bond of ethane, is probably due partly to the reduced overlap and partly to the peculiarities of hybridisation. The fact that the N—N bond of N_2O_4 is even weaker than that of hydrazine (the force constants being $1·5 \times 10^5$ and $3·6 \times 10^5$ dynes per cm., respectively) can be explained as caused by reduced overlap in the N—N bond of N_2O_4 consequent upon the high dipole in each NO_2 group, thus $\overset{-}{O}_2\overset{+}{N}—\overset{+}{N}\overset{-}{O}_2$.

Again, the dissociation energy of the central C—C bond of glyoxal appears to be lower than that of ethane, in spite of the relatively small C—C distance (about 1·47 A.) This circumstance can be explained by the high electronegativity of the carbon atoms and consequent small size of the carbon orbitals, which leads to a reduced overlap.

Finally, several anomalies can be explained if it be assumed that pairs of electrons in parallel filled atomic orbitals repel each other strongly. This repulsion is the electron pair bond theory analogue of the antibonding orbitals of the molecular orbital theory. The fact that the oxygen molecule has two unpaired electrons, as shown by its paramagnetism, has been difficult to explain on this theory, although it follows quite naturally from the molecular orbital theory. If it is supposed, however, that the $2p_z$ atomic orbitals overlap to form a $p\sigma$ bond, the doubly filled orbitals will repel one another and set themselves along axes at right angles to one another, whilst each doubly filled orbital is along an axis parallel to that of the singly filled orbital of the other atom, giving the configurations $2p_x{}^2 2p_y 2p_z$ and $2p_x 2p_y{}^2 2p_z$ on the two atoms, respectively. Walsh supposes there to be an attractive interaction of a single electron with a parallel lone pair, so that the oxygen molecule has a lower

energy state than would be represented O=O. With nitrogen, of course, there is no effect of this kind at all, as all the $2p$ orbitals are only singly occupied, but this repulsion must cause a considerable reduction in the bond strength of the fluorine molecule and to a less extent of the chlorine molecule.

Repulsion of adjacent filled atomic orbitals appears to occur in the carbon tetrachloride and carbon tetrafluoride molecules, thereby accounting for the fact that the carbon-halogen bond energies are lower than the silicon-halogen bond energies in the corresponding silicon halides. It may be assumed that the much larger size of the silicon atom reduces the repulsion between the orbitals.

ORGANIC CHEMISTRY. By A. W. JOHNSON, M.A., Ph.D., A.R.C.S., University Chemical Laboratory, Cambridge.

CHLORAMPHENICOL; CHLOROMYCETIN.—Chloramphenicol is the generic name applied to an antibiotic first isolated from the filtrates of submerged aerated cultures of a new *Streptomyces* sp., *S. venezuelæ* (Ehrlich, Gottlieb, Burkholder, Anderson and Pridham, *J. Bact.*, 1948, **56**, 467), obtained from a sample of field soil collected in Venezuela (Ehrlich, Bartz, Smith and Joslyn, *Science*, 1947, **106**, 417) and independently from an actinomycete isolated from a compost soil from Urbana, Illinois (Carter, Gottlieb, Anderson et al., *J. Bact.*, 1948, **55**, 409 ; *Science*, 1948, **107**, 113). The compound is, however, better known as chloromycetin, which is the trade mark adopted by Parke, Davis & Co. The new antibiotic is of considerable interest as it is active against several gram-negative bacteria and it has pronounced antirickettsial activity, *e.g.* in the treatment of scrub typhus and typhus fever, as well as some activity against viral infections (Smadel et al., *Science*, 1947, **106**, 418 ; 1948, **107**, 160 ; Smith, Joslyn, Gruheit, McLean, Penner and Ehrlich, *J. Bact.*, 1948, **55**, 425). Moreover it possesses a low toxicity and is well absorbed on preoral administration.

The active principle was isolated by a relatively simple extraction and adsorption technique (Bartz, *J. Biol. Chem.*, 1948, **172**, 445) and it was obtained as colourless needles or elongated plates, m.p. 149·7-150·7° ; $[\alpha]_D^{25}$ − 25·5° (ethyl acetate). It was a neutral compound, soluble in water to the extent of 2·5 mg./c.c. but very soluble in most organic solvents. Analysis indicated the formula $C_{11}H_{12}O_5N_2Cl_2$, and it exhibited the unique feature of containing both nitrogen and non-ionic chlorine. It was stable between pH 2 and 9 for more than 24 hours and it was unchanged on boiling

with water for 5 hours, but on the other hand was more than 87 per cent. inactivated at pH 10·8 in 24 hours at 25°. The ultra-violet absorption spectrum ($E_{1\,cm.}^{1\%}$ 2780 A. = 298) suggested that chloramphenicol (I) was a nitrobenzene derivative and this was confirmed chemically, *e.g.* by reduction, diazotisation and coupling with β-naphthol, when an orange-red precipitate was obtained, so that, in addition to the unusual feature of being a naturally occurring chlorine-containing compound, the antibiotic became the first naturally occurring nitro compound. (A second example has since been provided in that hiptagenic acid, which occurs as its glycoside, hiptagen, in the bark of the tree, *Hiptage mandoblata*, has been identified as β-nitropropionic acid ; Carter and McChesney, *Nature*, 1949, **164**, 575). Furthermore, on the basis of the absorption spectrum it was suggested that the chlorine was not directly attached to the benzene ring (Rebstock, Crooks, Controulis and Bartz, *J. Amer. Chem. Soc.*, 1949, **71**, 2458). Two alcoholic hydroxyls were revealed by the formation of a di-O-acetyl derivative, and carbonyl and primary amino groups were absent, although after hydrolysis with acid or alkali a base $C_9H_{12}O_4N_2$ (II) was obtained which formed an N-acetyl and a N:O:O-triacetyl derivative. In addition to this base, dichloroacetic acid was formed, and moreover reaction of (II) with methyl dichloroacetate re-formed chloramphenicol, which was therefore regarded as a N-substituted dichloroacetamide, $CHCl_2.CO.NHR$. The structure of (II) followed readily from the results of periodate oxidation, when the products were *p*-nitrobenzaldehyde, formaldehyde, formic acid and ammonia, and thus the amino group must be in the 2-position of the propyl chain. Hence the structure (I) was derived for chloramphenicol and the above reactions may be represented :
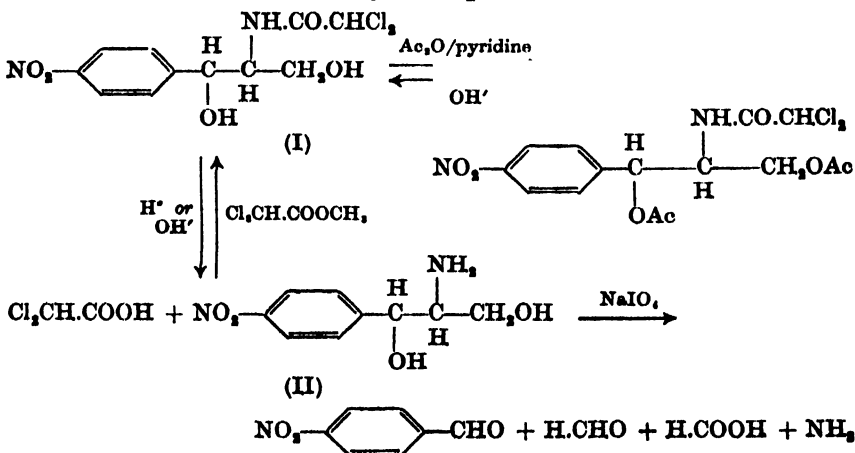
The stereochemical configuration of chloramphenicol was related to the ephedrine series and it was shown, by considerations of stability and optical rotation of derivatives, that it belonged to the ψ-ephedrine series having the D-($-$) *threo* configuration (as in I).

Three different syntheses of chloramphenicol were announced at the same time as the proof of its structure. In the first (Controulis, Rebstock and Crooks, *ibid.*, 2463) the carbon skeleton was built up by the reaction of benzaldehyde and nitro-ethanol and the series of reactions employed was as follows :

$$\rangle\!\!-\!CHO + CH_2NO_2.CH_2OH$$

$$\downarrow$$

$$\langle\quad\rangle\!\!-\!CHOH.CH(NO_2).CH_2OH$$

$$\downarrow H_2(Pd)$$

$$\rangle\!\!-\!CHOH.CHNH_2.CH_2OH$$

$$\downarrow \text{fractional crystallisation}$$
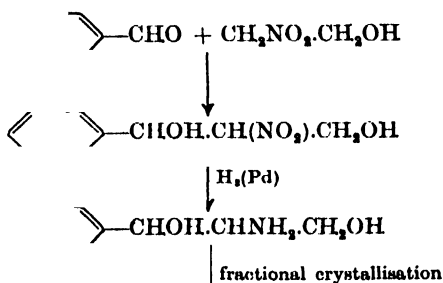
Amorphous *threo* base

O:N-diacetyl derivative

O:O:N-triacetyl derivative

$$\downarrow HNO_3$$
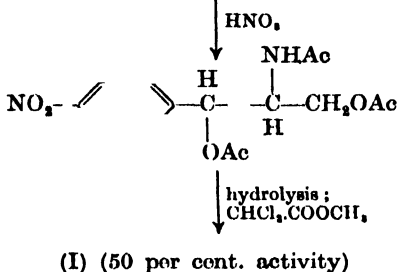
Crystalline *erythro* base

$$\downarrow CHCl_2.COOCH_3$$

$$\begin{array}{c} NH.CO.CHCl_2 \\ OH \quad | \\ C\!\!-\!\!-\!\!-\!\!C\!\!-\!\!CH_2OH \\ H \quad H \end{array}$$

$$\downarrow Ac_2O ; HNO_3$$

$$\begin{array}{c} OAc \quad NH.CO.CHCl_2 \\ | \qquad | \\ \!\!-\!C\!\!-\!\!-\!\!-\!\!C\!\!-\!\!CH_2OAc \\ H \qquad H \end{array}$$

$$\downarrow \text{hydrolysis}$$

$$\begin{array}{c} OH \quad NH.CO.CHCl_2 \\ | \qquad | \\ NO_2\!\!-\!\!\langle\quad\rangle\!\!-\!C\!\!-\!\!-\!\!-\!\!C\!\!-\!\!CH_2OH \\ H \qquad H \end{array}$$

(Biologically inactive)

$$\begin{array}{c} H \quad NHAc \\ | \qquad | \\ NO_2\!\!-\!\!\langle\quad\rangle\!\!-\!C\!\!-\!\!-\!\!C\!\!-\!\!CH_2OAc \\ | \qquad H \\ OAc \end{array}$$

$$\downarrow \begin{array}{l} \text{hydrolysis ;} \\ CHCl_2.COOCH_3 \end{array}$$

(I) (50 per cent. activity)
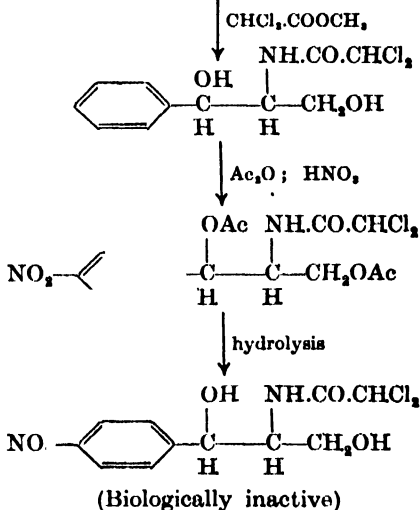
The resolution of the optically inactive product (I) so formed was achieved by fractional crystallisation of the *d*-camphorsulphonates, when the D-($-$) compound was identical in every respect with

chloramphenicol and the D-(+) enantiomorph had < 0·5 per cent. of the biological activity.

Further syntheses were directed towards preparations of the base (II) (Long and Troutman, *ibid.*, 2469, 2473) which might be suitable for large-scale production, *e.g.*

$$PhCHO + CH_3NO_2 \longrightarrow PhCHOH.CH_2NO_2 \xrightarrow{CrO_3}$$

$$PhCO.CH_2NO_2 \xrightarrow[Ac_2O]{reduction;} Ph.CO.CH_2NHAc \xrightarrow[NaHCO_3]{HCHO}$$

$$PhCO.CHNHAc.CH_2OH \xrightarrow{H_2/Ni}$$

$$PhCHOH.CHNHAc.CH_2OH \xrightarrow{Ac_2O} PhCHOAc.CHNHAc.CH_2OAc$$
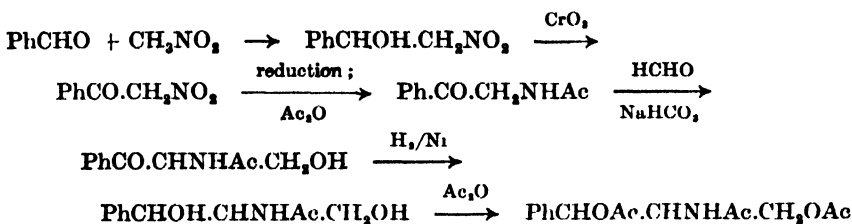
Nitration gave the *p*-nitro derivative which yielded (II) on hydrolysis. A closely related synthesis was described using *p*-nitroacetophenone as the starting material. Chloramphenicol is thus the first antibiotic of major importance to be synthesised in quantity.

VITAMIN B_{12}. THE ANTI-PERNICIOUS ANÆMIA (APA) FACTOR.— The early work on the anti-pernicious anæmia factors from liver was summarised by SubbaRow, Hastings and McElkin (*Vitamins and Hormones*, New York, 1945, **3**, 237) and emphasised the variation in the chemical preparations to which activity had been attributed. The considerable progress of the previous twenty years since the demonstration by Minot and Murphy (*J. Amer. Med. Assoc.*, 1926, **87, 470**) that liver was effective in the dietary treatment of pernicious anæmia patients led to the conclusion that it would be " reasonable to expect the isolation and identification of the active material to be an attainable object." This object was fulfilled to a large part in 1948 when two groups of workers independently isolated from liver, crystalline products in the form of small red needles which were highly potent in the treatment of the disease (Rickes, Brink, Koniuszy, Wood and Folkers (*Science*, 1948, **107**, 396 ; **108**, 134) and Smith (*Nature*, 1948, **161**, 638 ; **162**, 144)). The two products were later shown to be identical (Brink *et al.*, *J. Amer. Chem. Soc.*, 1949, **71**, 1854 ; Smith *Proc. Roy. Soc.*, in the press), and the factor was named vitamin B_{12}. The original authors showed that the red colour was due, at least in part, to the presence of co-ordinately bound cobalt and that, in addition, nitrogen and phosphorus were present, although sulphur was absent. This is the first isolation of a naturally occurring cobalt compound, although this element has long been recognised as an essential factor in ruminant nutrition (*e.g.* Tosic and Mitchell,

Nature, 1948, **162**, 502). When tested for activity in the clinical treatment of pernicious anæmia, positive responses were obtained with doses of 1–5 μg. daily and the new vitamin is thus one of the most potent physiologically active compounds (West, *Science*, 1948, **107**, 398). Moreover, vitamin B_{12} proved to be a highly active growth factor for the organism *Lactobacillus lactis* Dorner (Shorb, *ibid.*, 397 ; *J. Biol. Chem.*, 1947, **169**, 455) and this was used by the American workers as the basis of a method for microbiological assay. The vitamin is also a growth factor for chicks reared on a diet deficient in animal protein factor (Ott, Rickes and Wood, *ibid.*, 1948, **174**, 1047 ; *cf.* also Stokstad *et al.*, *ibid.*, 1949, **180**, 647, who conclude that another factor is also required), for rats and for baby pigs (Johnson and Neumann, *ibid.*, 1949, **178**, 1001).

The isolation of the vitamin from crude liver, where it occurs in very low concentrations, is a lengthy procedure which must involve no acid or alkaline treatments, as these were shown to cause deactivation (*e.g.* Rickes *et al.*, *Science*, 1948, **108**, 134). The purification has been described by the English workers (*e.g.* Smith and Parker, *Proc. Biochem. Soc.*, 1948, **43**, viii ; Smith, *Proc. Roy. Soc.*, in the press) and depended on multiple adsorptions and extractions, although it was complicated by the fact that the red colour was not apparent until relatively pure concentrates had been achieved. A third isolation of vitamin B_{12} from liver (Ellis, Petrow, and Snook, *J. Pharm. Pharmacol.*, 1949, **1**, 60) has been reported and it has been shown that this product is identical with the earlier preparations (Brink *et al.*, *J. Amer. Chem. Soc.*, 1949, **71**, 1854). The early stages in the isolation depended entirely on the microbiological assay which was carried out in the Glaxo laboratories by determinations of the growth response of *L. lactis* Dorner by the cup plate assay (Cuthbertson *et al.*, *Analyst*, 1948, **73**, 334 ; *Proc. Biochem. Soc.*, 1949, **44**, v). The American methods for B_{12} assay using this organism have also been described, although it is likely that different strains were used (Shorb and Briggs, *J. Biol. Chem.*, 1948, **176**, 1463 ; Caswell, Koditschek and Hendlin, *ibid.*, 1949, **180**, 125). Shive, Ravel and Eakin (*J. Amer. Chem. Soc.*, 1948, **70**, 2614) and Wright, Skeggs and Hutt (*J. Biol. Chem.*, 1948, **175**, 475) have shown that thymidine (I), in relatively high concentrations, will allow the growth of *L. lactis* Dorner on B_{12}-deficient media, and the interrelationship of purines and vitamin B_{12} has been discussed by Shive *et al.* (*ibid.*, 1948, **176**, 991) and Tomarelli *et al.* (*ibid.*, 1949, **179**, 485). The existence of thymidine, the two clinically active red substances and a fourth microbiologically active component in liver extracts can be demonstrated by a com-

bination of partition chromatography together with microbiological assay on a solid medium (Cuthbertson and Smith, *Proc. Biochem. Soc.*, 1949, **44**, v ; **45**, xii ; Winsten and Eigen, *J. Biol. Chem.*, 1949, **177**, 989). The rather complex growth requirements of *L. lactis* Dorner (*e.g.* Greene, Brook and McCormack, *ibid.*, 1949, **178**, 999 ; Shaw, *J. Pharm. Pharmacol.*, 1949, **1**, 695, 701) have led other workers to recommend *L. leichmannii* 313 as a test organism for the crystalline anti-pernicious anæmia factor (Hoffmann, Stokstad, Franklin and Jukes, *J. Biol. Chem.*, 1948, **176**, 1465 ; Lees, Emery *et al.*, *Proc. Biochem. Soc.*, 1949, **45**, ii ; *J. Pharm. Pharmacol.*, 1949, **1**, 705) as well as for the " animal protein factor " which is closely related to vitamin B_{12} (Skeggs *et al.*, *J. Biol. Chem.*, 1948, **176**, 1459 ; Stokstad *et al.*, *ibid.*, 1949, **180**, 647).

The difficulties of isolation of vitamin B_{12} from liver naturally led to a search for alternative sources and the Merck group (Rickes *et al.*, *Science*, 1948, **108**, 634) have obtained products showing B_{12} activity from a number of other sources, and from the culture broths of *Streptomyces griseus*, the species used for streptomycin production, they were able to isolate crystalline vitamin B_{12}, identical with that obtained from liver. Full details of the experimental procedure are not yet available.

Meanwhile several groups of workers had begun an investigation of the chemical properties of crystalline vitamin B_{12} and it was soon established that the molecular weight was of the order of 1600 and that the approximate formula was $C_{61-64}H_{86-92}N_{14}O_{13}PCo$ (Brink *et al.*, *J. Amer. Chem. Soc.*, 1949, **71**, 1854). The refractive indices of the crystals were characteristic (Rickes *et al.*, *Science*, 1948, **108**, 634) and the absorption spectrum showed bands at 2780, 3610 and 5500 A. (Ellis, Petrow and Snook, *loc. cit.* ; Brink *et al.*, *loc. cit.*). Vitamin B_{12} is a polyacidic base (potentiometric titration) and solutions are optically active, $[\alpha]_{6563}^{23} = -59 \pm 9°$. On heating, the crystals blacken at 210–220° but do not melt below 300°. Mild acid hydrolysis caused the liberation of phosphate (Ellis, Petrow and Snook, *J. Pharm. Pharmacol.*, 1949, **1**, 287) and, although more vigorous acid hydrolysis failed to reveal any amino-acids, these authors (*ibid.*, 1949, **1**, 735) have claimed that 2-amino-1-propanol is liberated, which was detected by its reaction with ninhydrin and provisionally identified by its behaviour on paper chromatograms. Apart from this compound, there is produced during the acid hydrolysis a new basic compound, 5:6-dimethylbenziminazol (II), the structure of which was confirmed by its synthesis, and vitamin B_{12} was therefore assigned the formula (III) (Brink and Folkers, *J. Amer. Chem. Soc.*, 1949, **71**, 2951):

┌── O ────┐

CH.CH₂.CHOH.CH.CH₂OH

$$CH.CH_2.CHOH.CH.CH_2OH$$

N

OC   CH

N   C.CH₃

C

OH

(I)

CH₃   NH

       CH

CH₃   N

(II)

$$C_{53-54}H_{77-91}N_{12}O_{13}PCo$$

CH₃   N

       CH

CH₃   N

(III)
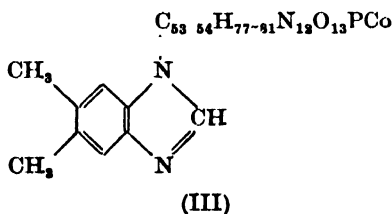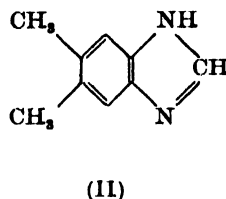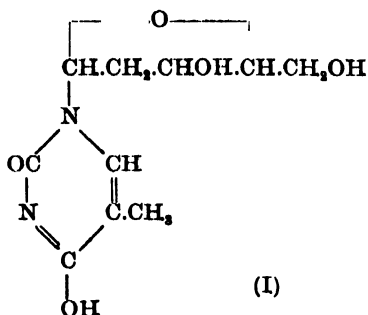
Holliday and Petrow (*J. Pharm. Pharmacol.*, 1949, **1**, 734) claim to have identified (II) by means of its characteristic absorption spectrum in the acid hydrolysis product of vitamin B_{12}, and they also obtained spectroscopic evidence for the existence of two unidentified 1-substituted-5:6-dimethylbenziminazoles in this product. Alkaline fusion of vitamin B_{12} (Brink *et al.*, *J. Amer. Chem. Soc.*, 1949, **71**, 1854) gave volatile products which gave colorations with *p*-dimethylaminobenzaldehyde. This test, although far from specific, could indicate the presence of pyrroles. Purines have not been detected in B_{12} hydrolysates.

Catalytic hydrogenation of solutions of vitamin B_{12} (Kaczka, Wolf and Folkers, *ibid.*, 1949, **71**, 1514) yielded a dark brown solution which changed to red on aerial oxidation. From the latter, a new crystalline, biologically active material was obtained, and was designated as vitamin B_{12a}. The existence of more than one red chemically active factor in liver was recorded by Smith in his first paper (*Nature*, 1948, **161**, 638 ; *cf. Proc. Biochem. Soc.*, 1949, **44**, v) and the crystallisation of a second compound in the form of small rod-like crystals has been reported recently by the Lederle group (Pierce *et al.*, *J. Amer. Chem. Soc.*, 1949, **71**, 2952). The absorption spectrum showed peaks at 2730, 3510 and 5250 A. and the product was biologically active in the assay with *L. leichmannii* 313 and in the chick assay (Stokstad *et al.*, *J. Biol. Chem.*, 1949, **180**, 647). This compound was named vitamin B_{12b} and a similar crystalline product was also obtained from the cultures

of *S. aureofaciens* (used for the production of the antibiotic aureo-mycin).

It is certain that very rapid progress will be made in the chemistry of the anti-pernicious anæmia factors and further advances may well be reported even before this account is published, but, what-ever the future may hold, the chemical isolation of vitamin B_{12} will always rank as an outstanding achievement in the chemistry of naturally occurring compounds.

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., F.R.S.E., The Univer-sity, Glasgow.

MAJOR EARTH STRUCTURES AND TECTONIC GEOLOGY.—It is fitting to place at the head of these " Advances " a brief preliminary notice of what is perhaps the most important book on earth structures since E. Suess's *Das Antlitz der Erde*, Dr. W. F. Hume's work on " Ter-restrial Theories. A Digest of various Views as to the Origin and Development of the Earth and their Bearing on the Geology of Egypt " (*Egypt: Geological Survey*. Government Press, Cairo, 1948. Pp. xlviii + 522, Index (separately paged) 160 pp., 45 plates and map in pocket, 37 figs.). It is modestly subtitled a " Digest," but it is much more than that ; it is a connected and reasoned survey of earth theories culled from no fewer than 307 major and minor works on the subject in most of the languages of science. The magnificent detailed index covers 160 closely printed pages of small quarto size. The mere physical labour of this compilation alone, not to speak of the intellectual labour, must have been enormous.

The Introduction gives some of Dr. Hume's " Personal Reflec-tions " on the topics covered by the book. Then follow chapters on the Nature of the Universe, Nature and Origin of the Solar System, Theories of the Origin of the Earth, Nature of the Earth's Internal Structure, Isostasy, Radioactivity and Convection Currents, Con-tinents and Oceans (including Continental Drift) and with an Appendix covering newer papers on the subject (mainly 1939–40), Nature of Pre-Cambrian Continental Areas and, finally, Considera-tions regarding Presence or Absence of Life in Pre-Cambrian Times. While the bearing on the geology of Egypt is always kept in view, the discussion ranges over the whole earth, and it is greatly to the credit of the Geological Survey authorities of Egypt to have published such an important and world-ranging work.

In the Third William Smith Lecture of the Geological Society of London, Professor F. A. Vening Meinesz reviewed hypotheses of

convection currents in the earth in relation to major tectonic phenomena (*Quart. Journ. Geol. Soc.*, CIII, 1948, 191–207). It is very difficult to summarise this closely-knit lecture in a short paragraph. The hypothesis of convection currents seems to explain the main tectonic features of the East Indian arcs, the most closely investigated area of tectonic disturbance on the earth. The solution involves the presence of convection currents which sink below the basins and rise beneath the tectonic belts. The author also touches on the problem of the antipodal relations of the continents and oceans which have led to the formulation of the tetrahedral theory of the earth. He rejects the view that the earth, in shrinking, tends towards a tetrahedral deformation. A more satisfactory explanation is found in a system of major convection currents which were present in the earlier stages of the cooling of the earth, rising currents towards the corners of the hypothetical tetrahedron, descending currents in the opposing directions beneath the major basins.

The Fourth William Smith Lecture, delivered by Professor P. Eskola, dealt with " The Problem of Mantled Gneiss Domes " (*Quart. Journ. Geol. Soc.*, CIV, 1949, 461–76). In many orogenic zones dome-shaped structures consisting of gneisses occur, which have a mantle of sediments with their stratification parallel to their contacts with the dome and the foliation of the gneiss. Mantled domes in the Karelidic orogenic zone of eastern Finland show variable characters, but in most of them the upper part of the dome has become migmatised and granitised during the doming process. It has a veined structure and a potash-rich " ideal-granitic " composition, although its original composition may have been granodioritic or quartz-dioritic. Similar domes are found in the Appalachians and in the Alps, but in the latter they have been greatly deformed.

A necessary condition for the production of mantled domes is that the region should have been subjected to two orogenic revolutions—in Finland, the Svecofennidic and Karelidic. They apparently represent early granitic intrusions of orogenetic character, later eroded, levelled and covered with a mantle of sediments. During the second orogenic cycle the pluton was mobilised anew and new magma was injected into the plutonic rocks at the same time as it was converted into gneiss, thus causing the migmatisation and granitisation or palingenesis. Professor Eskola finally speculates whether such concentrations of granitic matter in orogenic zones may be a consequence of convection currents consisting mainly of granitic material which soaks into the older orogenic structure, causing it to swell up into domes.

The paper by A. Rittmann, " Zur Thermodynamik der Orogenese " (*Geol. Rundsch.*, XXXIII, 1942, 485–98) defies brief summary. It is based, of course, on his larger work *Die Vulkane und ihre Tätigkeit* (1936) which has recently appeared in a revised Italian edition (*Vulcani : attività e genesi*, Napoli, 1944). Rittmann ascribes tectonic phenomena mainly to the distribution of temperature in the earth's crust. Accordingly in this theory earth structures are closely associated with volcanism and plutonism (in Read's sense). This paper is a brief summary from the geotectonic point of view of his larger work. It deals in succession with such topics as the mechanical equivalence of kraton and orogen ; energy-sources in geotectonics ; equilibrium in the earth's crust ; fundamental differences between kratons and orogens ; geosynclines ; folding ; uplift and plutonism ; border-deeps ; undations ; orogenic, foreland and backland volcanicity ; geothermy during orogenesis ; heat economy in orogenesis ; phases of orogeny ; continental geosynclines ; continental drift and the Mid-Atlantic Rise.

V. Oppenheim's study of the " Structural Evolution of the South American Andes " (*Amer. Journ. Sci.*, 245, 1947, 158–74) shows that the Andean orogenic belt is divisible into two main provinces of differing geological characters. The western cordilleras are built of an enormous and almost continuous granitoid batholith associated with volcanic rocks. It has a normal block-faulted structure such as would be produced by vertically-acting forces. The age of the uplift is mainly Upper Mesozoic. On the other hand the eastern cordilleras are composed of sedimentary and metamorphic rocks often with a crystalline basement exposed in the cores of the folds. The ages of the sediments vary from early Palæozoic to late Tertiary, and geosynclinal conditions of deposition are clearly indicated. Structurally the ranges are mainly block-faulted, but there is thrusting on the easternmost margins. The age of the uplift is late Tertiary to Quaternary.

The western batholith thus acted as a borderland to the eastern geosynclinal troughs, thus explaining the thrusting of the eastern ranges against the continental foreland. This concept eliminates the necessity for a hypothetical Pacific continent advocated by some authors. The Andean orogenic belt is thus ascribed to the slow vertical growth of the western batholith.

In a second paper, " Theory of Andean Orogenesis," Oppenheim (*Amer. Journ. Sci.*, 246, 1948, 578–92) suggests that the western cordillera originated from a volcanic island-arc similar to those that form the Aleutian and Caribbean arcs. The development culminated in the formation of an igneous range, separated by a geosynclinal

depression from the continental land mass, and bordered by a deep oceanic trough. He stresses the parallel with the arcs that fringe the east Asiatic coast. By this theory the unity of the circum-Pacific belt in regard to structure, volcanism and seismicity, is brought out. The whole unitary phenomenon of the circum-Pacific belt is regarded as the expression of deepseated subcrustal convection forces which are still in active operation.

A. J. Eardley advances somewhat similar ideas in regard to " The Palæozoic Cordilleran Geosyncline and Related Orogeny " (*Journ. Geol.*, LV, 1947, 309–42). In North America the cordilleran geosyncline in Palæozoic times consisted of two main troughs, a western or Pacific consisting of volcanic rocks, greywackes, slates and cherts in every system, folded, partly metamorphosed, and invaded by great batholiths of Mesozoic age ; and an eastern or Rocky Mountain trough containing marine limestones, shales and sandstones for the most part unmetamorphosed. The associated volcanic materials are mostly andesites and have been derived from the west as have also the sediments. It is suggested that a volcanic archipelago flanked the Pacific trough to the west, which was the site of continuous orogeny during the Palæozoic, and that conditions were very similar to those now existing in the island arcs of eastern Asia.

An interesting paper on " The Relation of Volcanicity and Orogeny to Climatic Change," by V. E. Fuchs and T. T. Paterson (*Geol. Mag.*, LXXXIV, 1947, 321–33), draws attention to " the possible effect of vast synchronous volcanic eruptions and associated earth-movement, not only on local but on world climate." In Part I Fuchs writes on " The Volcanics of East Africa and Pluvial Periods." He suggests that there is a close relationship between earth-movements, volcanicity, the blanketing effect of volcanic dust in the upper atmosphere (the " anti-radiation umbrella "), and the rise and fall of lake levels. The effect of volcanicity on world climate depends on the degree of synchronism between the great volcanic outbursts of the world.

Part II by T. T. Paterson deals with " The Cause of the Ice Age and the essential Rhythm of the Pleistocene." Pleistocene stratigraphical correlations show " the coincidence of widespread tectonic activity and glaciation and, in the tropics, the synchroneity of phases of crustal readjustment and major pluvial periods." Glaciation is basically due to epeirogenic alteration of relative heights and levels of land and sea, and is augmented by genetically related volcanicity. A part of Paterson's final paragraph is worth quoting in view of recent events : " . . . we may surmise the world has just witnessed the commencement of a new epoch during which the genus *Homo*,

brought into being during this great catastrophe [*i.e.* the last great deformation] will no doubt find time to flourish, to elaborate, and finally to extinguish itself."

In a paper on " The Geology of the Eastern Part of the English Channel " Professor W. B. R. King (*Quart. Journ. Geol. Soc.*, CIV, 1949, 327–38) brings together existing information on the geology and structure of south-eastern England and north-western France, with scraps of information relating to the rocks forming the floor of the eastern part of the English Channel. The echelon arrangement of the folds which is seen on both sides of the Channel is believed to continue on the floor of the intervening sea, and a map of probable submarine outcrops has been constructed. From Admiralty sources comes some evidence for a large outcrop of Triassic rocks in mid-Channel south of the Isle of Wight.

P. H. N. White and H. R. Lovely have described the " Gravity Data obtained in Great Britain by the Anglo-American Oil Company Limited " (*Quart. Journ. Geol. Soc.*, CIV, 1949, 339 -64), and their success in depicting and analysing the broad geological framework of the surveyed areas, as well as many minor structural features, notably in southern England and the eastern Midlands. Original discoveries have also been made by the use of the gravimeter, notably the subsurface configuration of the Carlisle Basin and folding beneath that town ; the true shape of the Cheshire Basin as a rift structure bounded by normal faults ; the eastward continuation of the Wharfe Anticline beneath the Permo-Trias ; the discovery of the Lindholme Anticline in south Yorkshire ; and of the marked anticlinal bulge around Gringley to the east of Gainsborough. The memoir is illustrated by a number of detailed maps.

N. L. Falcon has critically studied the available evidence on the " Tectonic History of the Malvern Hills " (*Geol. Mag.*, LXXXIV, 1947, 229–40) and comes to the following conclusions : (1) that the overfolding and overthrusting of the Silurian, and the overfolding of the Lower Old Red Sandstone on the western side of the range, took place during the interval between the end of the Lower Old Red Sandstone and the beginning of the Upper Coal Measures, probably during the violent movements which preceded the deposition of the Upper Coal Measures ; and (2) that the eastern side of the Malverns is to be regarded as a Triassic unconformity akin to that of Charnwood Forest, and not as a major post-Triassic fault.

M. F. Kuthan has made a very detailed study of " Die Oszillation, der Vulkanismus und die Tektonik von Reykjanes " (English, with summary in Czech) (*Sbornik Prirodov. Fac. Slovenskej Univ. Bratislava*, IV, 1943, 1–108). Reykjanes is the south-western

peninsula of Iceland, where swarms of small volcanoes, craters, hot springs, etc. are aligned along systems of fissures the main direction of which is N.E. S.W. But there are also secondary systems in which the main direction is N. 80° E., with a subordinate N. 5° E. direction. These secondary systems are wedged in between the main blocks. Kuthan envisages fracture tectonics caused either by a lateral stretching of the basement or by its dome-like or ridge-like uplift. Some blocks thus subside and many of the major fractures must reach down to magmatic foci. Whether the initiation of the movement of the blocks is in the sense of Wegener's drift theory or van Bemmelen's undation theory Kuthan leaves undecided ; but he makes the suggestion that the uplift of the Mid-Atlantic Rise, on which Reykjanes stands, may be the controlling factor.

A number of important memoirs on the tectonics of areas in the Near East and the Far East have recently been published. Thus, S. W. Tromp has offered " A Tectonic Classification of the Main Structural Units of the Anatolian Orogenic Belt " (*Journ. Geol.*, LV, 1947, 362–77) in which five tabular summaries give a valuable conspectus of the main structural and stratigraphical units, not only of the Anatolian belt but also of their possible continuations in the Balkans and northern Italy. The main clue was afforded by a study of the boundary between the so-called Arabian and Anatolian facies in southern Turkey, and the location of the " Ismit-Erzerum Line," a regional fault zone comparable with the San Andreas Fault in California, which includes the epicentres of the recent devastating earthquakes in Asia Minor. Stratigraphical and structural evidence indicates the continuation of this zone through the Balkans into northern Italy.

In a paper " Notes on the Geology of the Elburz Mountains, north-east of Tehran," Sir E. B. Bailey, R. C. B. Jones and S. Asfia (*Quart. Journ. Geol. Soc.*, CIV, 1948, 1–42) announce the discovery of Cretaceous limestone in the Lar valley, and of new tectonic events in the geological history of the district. Two separate earth movements, formerly confused, have been recognised. The earlier is late Cretaceous or earliest Tertiary, the later late Miocene, and the two events are separated by an extensive period of early Tertiary erosion. The earlier movement involves the thrusting of Old Red Sandstone over Lias ; the later is indicated by the steep intricate folding of Oligocene Green Beds. The latter, 3000 ft. thick, is a submarine volcanic accumulation rich in radiolaria, consisting mainly of rhyolitic and andesitic ashes. The great Quaternary volcano of Demavend grew with such extreme rapidity within the eroded

mountains of the Elburz that it disturbed and deflected the drainage of the region, and led to the formation of L. Lar which is now emptied by the downcutting of its spillway.

In his paper " Tektonik und Magma in der Insel Celebes und der indonesische Gebirgstypus," H. A. Brouwer (*Proc. Nederl. Akad. Wetensch.*, XLIV, 1941, 1–9) shows that in the central part of the island three main zones can be distinguished : (1) An eastern zone distinguished by the wide distribution of basic and ultrabasic igneous rocks, Mesozoic limestones and radiolarian cherts ; (2) a median zone of epi- to meso-metamorphic muscovite-rich schists ; and (3) a western zone distinguished by the wide distribution of granodioritic igneous rocks, biotite-schists, and more coastal types of sediments than in (1). Rocks of zone (2) are locally exposed within zone (1). This median zone is to be regarded as the eastern border region of the granitoid plutons and the younger lavas. Three orogenic types are distinguished : Andean (magmatic) type ; Alpine type character-ised by very great transverse shortening of the affected region ; and an Indonesian type which in many respects is intermediate between the other two. Like the Alpine, the Indonesian type started from a geosynclinal phase which was, however, diversified by rises (Schwellen).

T. K. Huang, chief geologist of the Geological Survey of China, has published a memoir " On Major Tectonic Forms of China " (*Nat. Geol. Surv. China. Geol. Mem. Ser. A*, No. 20, 1945, 165 pp.) which is a connected account of structural forms in China proper, but including also marginal regions such as the Karakoram and Lake Baikal in Siberia. The writer has not seen this memoir, but good reviews by R. T. C. (*Journ. Geol.*, LV, 1947, 59–60) and W. B. H. (*Geol. Mag.*, LXXXIV, 1947, 54–6) provide the reader with an adequate idea of its contents. In his treatment of continents and geosynclines, orogeny and epeirogeny, and the classification of genetic types, the author mainly follows the ideas of Stille and Argand. He groups the orogenic structures as Deckengebirge, Faltengebirge, Bruchfaltengebirge, and Blockgebirge, and presents the orogenic cycles (since the Cambrian) as Caledonian, Variscian (comprising three sub-cycles from late Devonian to the end of the Permian), Indosinian (late Trias to Lias), Yenshanian (in three phases from late Jurassic to the end of the Cretaceous), and the Himalayan (in three phases corresponding to those of the Alps). There follows a theoretical chapter on the geotectonic make-up of China. The growth of the Asiatic continent is regarded as due to the southward migration of geosynclines with their subsequent foldings outwards from the old Angara Massif, an illuminating

conception which parallels to some extent a similar view of the growth of Europe outwards from the Baltic Shield.

In his " Remarks on the Tectonic History of Yunnan with special reference to its Relations to the Type of the young Orogenic Deformation," P. Misch (*Bull. Geol. Surv. China*, XXV, 1945, 47–154) discusses the tectonics of Yunnan in some detail, because the types of late deformation (Late Mesozoic ; Early Tertiary) are different in different parts of the region, and seem to have been controlled by what had happened in earlier periods. Three main tectonic units are involved : (1) the East Yunnan Basin which, during many of the periods of subsidence, was the western part of a larger basin ; (2) the Central Yunnan Swell which, at a late period, was converted into a basin ; and (3) the West Yunnan Para-syncline ; the strike of all three being nearly N. to S. Prior to the latest folding and since the Pre-Cambrian only epeirogenic movements took place. In the Pre-Cambrian both orogeny and epeirogeny occurred ; subsequently epeirogeny occurred several times in the Palæozoic and Mesozoic. In the late orogeny referred to above the East Yunnan belt shows " sinotype " deformation which is intermediate between Stille's alpinotype orogeny of mobile geosynclinal areas, and his Germanotype disturbances of consolidated foreland areas. In western Yunnan pronounced alpinotype structures are found. Misch correlates these differences with long-continuing differences in the epeirogeny of underlying basement units.

A " major contribution to structural and historical geology " has been made by T. Kobayashi in his memoir " The Sakawa Orogenetic Cycle and its Bearing on the Origin of the Japanese Islands " (*Journ. Fac. Sci. Imper. Univ.*, Tokyo, Sect. III, V (Part 7), 1941, 219–578). The writer has not seen this memoir but an excellent review by J. Rodgers (*Amer. Journ. Sci.*, **246**, 1948, 57–61) gives Kobayashi's main conclusions. The Sakawa Orogenetic Cycle covers the Jurassic and Cretaceous. After two preliminary epeirogenic phases in the Jurassic there followed three orogenic phases : (1) Oga Phase in the Wealden, involving spectacular overthrusting and batholithic intrusion ; (2) Oshima phase, of late Neocomian age, represented by considerable folding but not, in Rodger's opinion, as important as the other two ; and (3) Sakawa phase, in Cenomanian time. This is the main orogeny and produced a remarkable zone of imbrication extending 600 miles from near Tokyo to western Kyushu. Following this main orogenic phase there was minor epeirogeny in the Senonian, and the extrusion of acid tuffs and lavas. The Sakawa orogenic cycle was accompanied by plutonism and metamorphism on the grand scale.

During the war the U.S. Navy accumulated vast numbers of soundings in the Pacific Ocean. Combining these with those already existing on the charts, it has been found possible to construct far more detailed and accurate bathymetrical charts of the area than heretofore. H. H. Hess has extracted the geological significance from the first of these new charts to be published in a paper on " Major Structural Features of the Western North Pacific, and interpretations of H.O. 5485 Bathymetrical Chart, Korea to New Guinea " (*Bull. Geol. Soc. Amer.*, **59**, 1948, 417–46). This chart is provided with the paper and is a remarkable production.

The most striking topographical and structural features are the enormous elongated trenches or deeps from Japan to Palau, which are more continuous than was previously indicated. East of this zone of deeps a portion of the North Pacific basin is shown which differs markedly in topography, structure, and petrology from the island-arc provinces to the west. These zones are separated by the so-called " Andesite Line." The concave side of the curved deeps includes from one to three parallel geanticlinal swells on which volcanic islands are situated. In general the eastern and southern belts of arcs and mountains are related to Late Cretaceous-Early Tertiary deformation which has continued spasmodically up to Recent time. The western belt, which includes southern Japan, the Ryukus, Formosa and the western Philippines, is probably the product of mid-Mesozoic deformation. It is significant that both deformations have associated belts of peridotite intrusions.

In a closely-argued paper, " Erosion and Tectonics in the East African Rift System," F. Dixey (*Quart. Journ. Geol. Soc.*, CII, 1946, 339–88) suggests that the Rift System has developed mainly from an ancient series of fractures dating from the later Jurassic, and that it is due in part only, and that often a minor part, to post-Tertiary fracturing. Consideration of the Karroo and Jurassic structures within the Rift Zone leads to the conclusion that major folding took place in later Jurassic time, locally raising the resistant pre-Karroo complex to great heights from which the high-level residual plateaus have been carved. The surviving tracts of Karroo and Jurassic sediments still occupy low-lying basins representing the original major synclines. Trough faulting followed within the elevated areas, bringing down strips of sediments which were subsequently eroded to form " ancestral rifts." Within the frame of this earlier rift system much of the Pleistocene rifting took place, forming narrow lake basins within an ancient topography. During the long history of intermittent continental uplift and concurrent base-levelling, the early fractures and trough faults have acquired a high

relief, largely owing to the removal of the weaker Karroo and Jurassic sediments. The vigorous criticism which followed Dr. Dixey's paper centred mainly on whether the elevated areas were of tectonic or erosional origin, and the extent of the post-Tertiary faulting.

A paper by L. C. King, " On the Ages of African Land-surfaces " (*Quart. Journ. Geol. Soc.*, CIV, 1949, 439–59), makes it clear that it is a tectonic as well as a morphological question. The primitive surface of the southern half of the continent is now regarded as modified " Gondwana " rather than Miocene, as hitherto. Later surfaces were carved by new cycles following mid-Tertiary and later uplifts. Thus, since the rough shaping of the continent the uplift is believed to have been not more than 2000 ft., except locally. Local deformation played a more important role in producing these surfaces than previously believed.

The paper by G. F. S. Hills on " The Rift Valleys of Africa " (*Amer. Journ. Sci.*, **246**, 1948, 171–81) is much compressed and difficult to summarise briefly. It presents a new theory based on gravitational deficiency to explain the rift systems. The author regards the raised areas as remains of ancient mountain ranges with much granite. The latter component is much thicker in mountain ranges than in continental basements. Radioactivity therefore raises the base of a range to a much higher temperature than the bases of continents. Hence the ranges rise after folding ; tension fissures develop on their flanks, and the rift valleys are believed to represent the fissures filled with basaltic lavas as they opened. This view, however, does not square with the known deficiency of gravity below the rifts ; and the author has to introduce a rather far-fetched theory of the " dispersal " of granite and basalt to the same extent beneath the plateaus and rifts respectively. But as basalt is the heavier material its loss caused a relative deficiency of mass beneath the rifts.

BOTANY. By PROFESSOR W. H. PEARSALL, D.Sc., F.R.S., University College, London.

ECOLOGY AND PLANT DISTRIBUTION.—The fact that the Ninth International Phytogeographical Excursion was held in Ireland this summer was responsible for the appearance of two long-awaited papers dealing with plant distribution in the British Isles. The first of these papers was Professor H. Osvald's account of vegetation of the British and Irish peat-mosses, the second was Professor Knud Jessen's comprehensive paper on his work on the plant remains of Irish peat-bogs.

Professor Osvald's paper (*Acta Phytogeog. Suecica*, **26**, 1949) is mainly descriptive of the vegetation types in the numerous bogs he has examined since he first started this work in 1921. Apart from the interesting details of bog vegetation in different localities which cannot be treated here, a particularly important part of this paper is the survey of the details of peat drainage and of the development of peat erosion in different instances. In general this results from inequalities of surface, which are most pronounced in areas with low winter temperatures, and which are subsequently accentuated by water movement or wind erosion. In tracing these features, many interesting details are given of natural development in British bogs.

Restricting the term bog to base-poor peats and their vegetation, there is, in general, as one passes westward from Sweden to the far western parts of the British Isles, a marked change in bog vegetation and bog type. In Sweden all bogs are of the " raised-bog " type, originating mainly in depressions or old lake basins but presenting a convex profile, but in the western British Isles " blanket-bogs " predominate, areas of peat which have overflowed all slopes except the steepest.

In the western bogs *Molinia cœrulea* and *Myrica gale* become increasingly abundant, whereas in Sweden these are confined to the bog margins and other wet areas. *Narthecium* and *Sphagnum papillosum* are also a striking feature of the western bog areas. Other notably western species are *Pinguicula vulgaris*, *Carex panicea*, *Rhynchospora fusca*, *Lycopodium selago*, *Campylopus atrovirens*, *Pleurozia purpurea* and *Sphagnum subsecundum*. *Sphagnum fuscum*, a characteristic species of the Swedish bogs, is very rare in Western Britain.

Species considered to be confined to blanket-bogs include such plants as *Orchis maculata*, *Pedicularis palustris*, *Luzula congesta*, *L. silvatica*, *Polygala vulgaris*, *Potentilla erecta*, *Deschampsia flexuosa*, *Schœnus nigricans*.

Professor Osvald dismisses as unsubstantiated the idea that the major peculiarities of the blanket-bogs are due to soil drainage. He thinks that the major changes in bog types are associated with climatic influences. This is a view which has been frequently expressed by British ecologists, notably by Tansley in *The British Islands and their Vegetation* and it has been shown by Pearsall (*J. Ecol.*, **26**, 298, 1938) that these drifts in bog vegetation and in climate are associated also with changes in the properties of the peat, which becomes more acid in drier climates, presumably owing to increased possibilities of oxidation. As similar effects are to be traced in any one locality where differences of drainage occur, it

seems evident that the climatic effects are largely dependent upon changes in the quality of the peat which they produce.

It is to be noticed in very wet climates that the contrast between raised-bogs and blanket-bogs tends to disappear just as differences in soil tend to become more uniform owing to the over-riding effect of the permanent saturation by water of the peat surface. Under these conditions the pH of the peat remains high, above pH 5, and soils are permanently deficient in oxygen. The type of bog found under these conditions has been described by Pearsall and Lind (*J. Ecol.*, **29**, 62, 1941).

Another enquiry into this type of problem has been carried out by D. A. Webb (*J. Ecol.*, **35**, 105, 1947) in describing the vegetation of Carrowkeel, a limestone hill in north-west Ireland, where on the summit plateau peat is developed above and in contact with the limestone, with little or no perceptible trace of mineral soil between the peat and the limestone. There is thus no evidence of a profile showing signs of leaching or normal soil development, and it is clear that the initial process of peat formation must have been the accumulation of humus immediately on the limestone surface. It is considered that the fairly high rainfall and the very low evaporation must have been the factors inducing this condition, and it is thought possible that the effect of peat itself, quite apart from base-deficient soil, may lead to peat formation becoming as it were auto-catalytic.

Some of the peculiar features of the far western bogs have been attributed to the possibility that sea-spray containing salt might be carried inland with great frequency, thus possibly affecting the character of the soil and its resultant vegetation. D. A. Webb has recently re-examined this question in surveying the acidity, chloride content, and other chemical features of Irish waters (*Proc. Roy. Dublin Soc.*, **24**, 215, 1947). He has concluded, in this connection, that there is a reasonable correlation between sodium and chloride content present in the surface waters and the possibility of contamination of soils by wind-borne sea-spray. Thus the far western stations examined show high figures for sodium and chloride irrespective of the type of rocks from which the waters are derived.

The second of the larger papers mentioned in the first paragraph of this review is Professor Jessen's report on late Quaternary deposits in Ireland and peat stratigraphy (*Proc. Roy. Irish Acad.*, **52B**, 88–290, 1949). The work falls into three parts. First comes an account of the stratigraphy of various peat deposits in different parts of Ireland—illustrated by admirable profile diagrams drawn to scale. Next comes a description of the species and material identified in

these deposits.   Finally there is a detailed account of the post-glacial development of the flora in Ireland.

In the late-glacial period, Ireland was an oceanic sector of the sub-arctic Birch-region of north-west Europe.   There were copses of birch (*Betula pubescens*) and stretches of open country, which in the west were covered by heaths rich in *Empetrum* and elsewhere by a vegetation of grasses and herbs whose character cannot be closely defined.

This was followed by a period in which open tundra-like vegetation and heath predominated, including plants like *Salix herbacea*, *Dryas octopetala*, *Betula nana* and much *Empetrum nigrum* in the north-west.

Later, in the post-glacial, came a Hazel-Pine period when the most of Ireland was covered by forest.   The climate was oceanic (for *Erica cinerea*, *E. Mackaii*, *E. tetralix* and *Hedera* were present), but there seems reason to believe that it was rather drier than in the following period and that it gradually became slightly warmer than at the present day.   A later period of much alder extension followed, when both holly and ivy also spread freely.   Bogs, both raised-bog and blanket-bog, began to develop, forming a highly humified peat. The climate was oceanic and appears to have been rather more moist than in the preceding period.   *Erica Mackaii* and *Eriocaulon septangulare* lived in the west of Ireland, and there is a suggestion (derived from the molluscan fauna of the raised beaches) that the temperature was normally higher than it is now.

Next came a decline in the forest area and the occurrence of pollen of *Plantago lanceolata*, indicating the development of pastures. *Myrica gale* is recorded from bogs in western Ireland.   At the end of the period pine and birch often extended on to the bog surface and peat formation came nearly to a standstill.   This is approximately the Bronze Age in time.   It was followed by marked climatic deterioration.   Thus the disappearance of trees increased with more rapid bog growth and the extension of cultivation.

The details of this work are thus invaluable to any study of the history of the Irish flora.   They raise again the problems associated with plant distribution in that country.   On the whole Professor Jessen takes the view that, during the last general glaciation, Ireland was treeless except for sporadic birch groves, perhaps mainly in the Allerød period.   Thus most of the woodland plants must have been absent, although there is clear evidence of the survival of considerable floras, mainly either tundra species or water and swamp plants. It appears from the present evidence that the vegetation developed in much the same way in Ireland as in the Dani-Scanian region.

Pinus sylvestris was, however, notably late in appearing in Ireland. The facts do not support any theory of a glacial forest-region near to and just south of Ireland but that the glacial timber-line must have been some considerable distance away. Professor Jessen points out that there is nothing in the evidence to exclude the possibility that the American element in the Irish flora survived at least in the later glacial period. On the other hand, the Lusitanian plants are not always so easily accounted for and some of them, like *Arbutus*, may be later tree immigrants into the island, although on the whole the species are light requiring plants growing on heaths, rocky places and pastures.

Somewhat similar problems have been discussed by A. and D. Löve in their *Studies on the origins of the Icelandic flora (Dept. Agric., Reykjavik*, B, No. 2, 1947). The particular problem they have investigated is the distribution of *Cakile* in Iceland. There are two similar species *C. maritima*, met with on European coasts, and *C. edentula*, which is American and which includes three sub-species. The latter is found in Iceland, almost continuously distributed on the west coast and only occurring sporadically elsewhere. It is a tetraploid species, $2n - 36$ in contrast to the European *C. maritima* which is diploid, $2n = 18$. The hypothesis is advanced that *C. edentula* has been dispersed from Iceland to America under the influence of oceanic drifts and that this has taken place since the last glaciation.

A useful general discussion of the origin of the Icelandic flora is also added. It is probable that at least 30 per cent. of the present flora of higher plants has been imported by man during the last 1200 years. A smaller number of species like *Cakile* may have been brought during the earlier post-glacial from other countries by sea currents, by birds or by wind, but the authors think that not more than 15 per cent. of the present flora can have migrated in this manner. Thus at least 50 per cent. of the present flora appears to have survived the latest glaciation and perhaps the whole Ice-Age in Iceland. Examples of these species are given.

TAXONOMY.—In continuing their studies on northern species on similar lines, A. and D. Löve have compiled a list of the chromosome numbers of northern plants so far as they are known (*Dept. Agric., Reykjavik*, B., No. 3, 1948). This is an extension of an earlier list and is a very valuable addition to the literature of this subject.

It has of course been evident, from a recent work, that the concepts underlying taxonomic studies have for some time been changing and extending. In this field there are, of course, the practical problems dealing with the effects of hybridisation and of

genetical changes as well as their impact on theories of taxonomy. An excellent example of the practical problems has been presented by D. H. Valentine in his studies of British primulas (*New Phyt.*, **46**, 229, 1947 ; and **47**, 111, 1948). Dr. Valentine has more recently considered some of the theoretical implications of these and relative problems in determining the units of experimental taxonomy (*Acta Biotheor.*, **9**, 75, 1949). In this paper the following definitions are envisaged :

1. *g*-ecospecies. Groups with the same chromosome number between which there are well-defined morphological, ecological and geographical differences and which, under artificial or natural conditions, are capable of only limited gene-exchange.

2. *a*-ecospecies. Groups differing in chromosome number between which there are well-defined ecological and geographical differences and which are capable of only limited gene-exchange.

3. ecotypes. Groups forming genetically distinct components of ecospecies, adapted to special types of environment and capable of unlimited gene-exchange.

4. cytotypes. Groups forming polyploid components of an ecospecies.

ZOOLOGY. By WILLIAM HOLMES, M.A., D.Phil., The University, Oxford.

PROTOZOA.—That deceptively simple creature *Amoeba* is still reluctant to yield up its secrets. Amoeboid movement, the form of living activity in which a mass of protoplasm changes its shape, flows, and progresses as a whole, seems such a simple case of the transformation of chemical energy into vital movement that one might expect from *Amoeba* to gain fundamental knowledge of protoplasmic activity. But a recent review of theories of amoeboid movement shows that advance is slow and fragmentary (de Bruyn, *Q. Rev. Biol.*, 1947, **22**, 1). The author emphasises how the various theories of the mechanism concerned have been biased by contemporary modes of interpretation of the structure of living matter : interpretations in terms of the structure of colloidal solutions of globular proteins, and of local surface tension changes, have given way to those based on the existence within the cytoplasm of a contractile sub-microscopic skeleton. But our actual knowledge goes only so far as the movements and changes that can be seen through the microscope. A great variety of inclusions can readily be seen in the protoplasm of

Amœba, and there is still need for the careful examination of its structure, by all the repertoire of microscopical technique. A substantial contribution to this description has been made by N. Andrèsen (*C.R. Trav. Lab. Carlsberg, Sér. chim.*, 1943, **24**, 139). His lengthy paper on the cytoplasmic components in *Amœba* contains direct observations on the mode of formation of pseudopodia, and on the existence of different states of the protoplasm, as represented in the classical terms plasmasol, plasmagel, hyaline cytoplasm and plasmalemma. All the inclusions are surveyed, by techniques varying from vital staining to the study of paraffin sections, and similar studies were made after centrifuging. It cannot be said that any startling conclusions arise from this work, but it should form a satisfactory basis for further studies of a physiological and histochemical character which are now being carried on in a concerted attack on *Amœba* in the Carlsberg laboratories.

The animal actually used in the Carlsberg studies is charmingly named *Chaos chaos* Linné, but it is not so very different from the *Amœba proteus* of the elementary text-book ; indeed, the very nomenclature of the Amœbas is in dispute, and for recent contributions to the discussion of the taxonomic characters of the group one may refer to notes by King and Jahn (*Science*, 1948, **107**, 293) and by Wilber (*ibid.*, 445).

Paramecium is still the subject of studies from all sorts of points of view. Woodruff has contributed an interesting historical article in discussion of the problem of who it was who first saw the creature, and it is illustrated by delightful reproductions of all the early drawings that were made of it (*Trans. Connecticut Acad.*, 1945, **36**, 517). Mast has written a long and careful account, supported by a most useful bibliography, of " The Food Vacuole in Paramecium," considering the process structurally and physiologically (*Biol. Bull.*, 1947, **92**, 31). The animal selects its food to some extent, the selection taking place in the tube leading from the " mouth " into the " pharynx." In forming a food vacuole the cilia in the pharynx force fluid with particles in suspension against the membrane over the distal end of the pharynx, producing a sac, the œsophageal sac. As the œsophageal sac enlarges particles become concentrated within it, largely owing to the passage of water through the membrane into the cytoplasm. Then the sac is pinched off, and becomes a food vacuole, probably as a result of the organised contraction of a group of cytoplasmic fibrils inserted upon that region of the ingestion apparatus. After the vacuole has left the pharynx it is drawn on a fixed course, probably by these fibrils, to the posterior end of the body, whence it slowly passes on a variable course to the

fixed point of ejection. There are great variations in the size of the vacuole during its passage, probably connected with great changes of pH which also occur—from 1·4 to 7·8. Protein, fat and starch can be digested.

Lund, in a similar but less detailed study of the feeding processes of various other ciliated protozoa, emphasises the importance in all of them of cytoplasmic fibrils, independently contractile, which he calls " endoral fibres " (*J. Morphol.*, 1941, 563). Andrews, too, shows the complexity of the permanent feeding apparatus of these animals, and in a study of " The Ingestion Organs in Folliculinids and Stentors " he gives a useful definition and standardisation of the terms used to describe the parts of the system (*J. Morphol.*, 1946, **79**, 419).

The use of the electron microscope has made possible the study of the structure of cilia, trichocysts and flagella. A recent description of the former is that of Jakus and Hall, who used the shadow-casting technique. They give very beautiful photographs, showing that a discharged trichocyst has a sharply pointed tip and a cross-striated shaft. The tip is opaque, shaped like a golf tee, and not flattened by the dehydration process involved in the technique. The dried shaft in contrast is greatly flattened. A cilium consists of a bundle of fibrils, about eleven in number, each fibril having a diameter of from 300 to 500 A. No sheath holding them together could be seen, so that if such a structure is present it must be very delicate (*Biol. Bull.*, 1946, **91**, 141). The structure of flagella is described by Foster et al. (*Biol. Bull.*, 1947, **93**, 114), and their work confirms the earlier account by H. P. Brown. They distinguished two types of flagellum : the first is composed of twisted fibrils in a rope-like arrangement ; the second has a shaft from which small cilia-like structures project.

Buchtal and Knappeis have compiled a bibliography of observations made on the structure of Protozoa by means of the polarised light technique, including observations on the birefringence of the flowing cytoplasm of axopodia and lobose pseudopodia, on cilia, myonemes etc. (" Die Doppelbrechung der einzelnen Zellen," *Tabulæ Biologicæ*, 1939, **19**, 346). Observations of structure made by this method can never become out of date, and the bibliography will have a permanent value.

Almost every month new papers appear revealing still further details of cytoplasmic specialisation within protozoan cells, particularly in the Ciliates. There is no doubt that these organisms contain a mass of " organelles " which can be made clear by ordinary visible light microscopy after suitable staining ; that is to say that

the Protozoa differ from the cells of Metazoa in that they have a greater variety of internal organisation on the microscopic level. Research has been particularly concentrated on what may be called the fibrillar system in ciliates. Much of this work has been done by G. and J. v. Gelei and by B. M. Klein. Their work is difficult to follow, partly because each tends to use individual techniques and does not take the trouble to relate his own observations to those of others. C. V. Taylor made a brave attempt to disentangle the subject in 1940 (in *Protozoa in Biological Research*, ed. Calkins and Summers). Here we must draw attention to a more recent review, by v. Gelei, entitled " Feinstrukturen einzelliger Organismen " (*Jena. Zeitschr.*, 1943, **76**, 199), and to an account of stages of differentiation of the sub-pellicular " silver-line " system by Klein (*Arch. Protistenk.*, 1942, **96**, 1). Both these articles are illustrated by beautiful photographs.

The fact that such remarkably complicated organelle-fibre systems can regularly be demonstrated in constant form within Ciliates makes it clear that, even though the techniques of fixation and staining are brutal and empirical, there must be some underlying regularity of living form. One looks forward, therefore, to the application to these animals of the most promising technique of phase-contrast microscopy, which can be applied to living cells or to well-fixed preparations. Now that this technique has been simplified and cheapened it may not be long before every student will be able to see more of the structure of a protozoan than any of his teachers has done till the present time. Accounts of a simple technique of phase-contrast are given by Kempson, Thomas and Baker (*Quart. J. micr. Sci.*, 1948, **89**, 351), and by Baker, Kempson and Brunet (*Quart. J. micr. Sci.*, 1949, **90**, 323).

The Status of the Protozoa.—It has repeatedly been stated that the Protozoa are not *unicellular* organisms, but rather *non-cellular*. This view arises partly from the meditations of those who study the protozoan organelles. Thus, at the end of the review cited above, v. Gelei writes : " no single cell of a Metazoan is equal to a Protozoan in complication or efficiency . . . in my opinion it is incorrect to compare a single-celled organism with a single metazoan cell ; one can only compare the single celled organism, which is a whole, with the whole Metazoan." It also arises from the argument that a cell is *defined* as a unit of a Metazoan organism, and therefore cannot be used to describe the whole of an organism that is not multicellular.

J. R. Baker has reconsidered the problem, and begins by seeking for a valid definition for the word cell (*Nature*, 1948, **161**, 548). He concludes that the only precise and valid definition is that a

cell is : " a mass of protoplasm, largely or completely bounded by a membrane, and containing within it a single nucleus formed by the telophase transformation of a haploid or diploid set of anaphase chromosomes." He writes : " It follows from this definition that a great number of Mastigophora, Amœbina, Heliozoa, and Sporozoa (*sensu stricto* = Telosporidia of Schaudinn) are single cells, which alternate between the diploid and haploid condition." Many Protozoa, on the other hand, are not cells. The Radiolaria provide some of the best examples ; any animal with a polyploid nucleus is not a cell. Amongst the Ciliates forms such as *Opalina* are obviously multinuclear and so non-cellular ; forms with a macro- and micro-nucleus are at the very least triploid, and in fact probably highly polypoid.

Baker's arguments should be read and discussed ; it is refreshing to see an old controversy taken on to new ground where the argument can be based on the marshalling and opposing of facts.

THE MALARIAL PARASITE.—The discovery of the part played by the mosquito in the transmission of the parasite *Plasmodium* led to the working out of the life-cycle that is now to be found in text-books. For years, however, there has remained an important gap in our knowledge of the cycle. The sporozoite stage, injected into the blood system of the vertebrate host by the mosquito, was des-cribed by Schaudinn as entering a red blood corpuscle. In fact, however, Schaudinn's observation has never been repeated, and there has been, in human malaria for example, a mysterious period of about ten days, the incubation period of the disease, in which no parasites can be found in the erythrocytes in the circulating blood. It has long been suspected that there is some pre-erythrocytic (exo-erythrocytic) form of the parasite, developing in the internal organs during this quiescent period. In 1936 and 1937 Raffaele, and James and Tate, demonstrated that in the malaria of birds, caused by *Plasmodium elongatum*, such a stage does occur, involving a cycle of schizogony.

The search for a similar stage in the mammal is of the needle and haystack kind, for the few sporozoites in the mosquito's saliva are disseminated by the bloodstream, and are infinitely small in relation to the volume of the body of the host they occupy. Shortt, Garnham and Malamos faced this difficulty in 1948, and attempted to overcome it by injecting a tremendous dose of sporozoites, far greater than the normal input from a mosquito bite, into the blood-stream of a monkey of the species *Macaca mulatta*. The monkey parasite, *P. cynomolyi*, is very similar in morphology and known life cycle to the *P. vivax* of man. A few days after injection the animal was

killed, and the enormous labour involved in the study of sections of every tissue and organ in the body was rewarded by the discovery, in the monkey's liver and in its liver only, of plasmodial masses which could be nothing else but a pre-erythrocytic stage of the malarial parasite (*Brit. Med. J.*, 1948, i, 192). They then turned to man. A patient requiring the artificial inoculation of malarial parasites as part of the treatment for general paralysis volunteered as a subject, and he was infected by allowing large numbers of mosquitoes infected with *P. vivax* to bite him, and by intravenous inoculation of quantities of the salivary glands of the same mosquitoes. Seven days after the first inoculation a minute biopsy of his liver was taken, by a simple and painless technique, and sections of this specimen revealed plasmodial masses studded with chromatin particles like those previously seen in the monkey. The missing stage was found, and we now know that, if this exo-erythrocytic stage in the liver could be eradicated by chemotherapy or other means, the disease malaria could be cured before it had given rise to any symptoms (Shortt, Garnham, Covell and Shute, *Brit. Med. J.*, 1948, i, 547).

A later study of the liver of a monkey, taken 3½ months after sporozoite infection of the blood-stream, showed that schizogony was still taking place in the exo-erythrocytic bodies in the liver. Here there is a pathological basis for the mysterious clinical phenomenon of the tendency of benign tertian infections to relapse repeatedly in spite of prolonged antimalarial treatment, and for the reappearance of erythrocytic forms of *Plasmodium* after the blood has been completely cleared of parasites (Shortt and Garnham, *Brit. Med. J.*, 1948, i, 1225).

A second experiment on a human volunteer has recently been carried out using *P. falciparum*, the parasite causing the malignant tertian form of the disease, which is responsible for most deaths from malarial infection. In this case also a pre-erythrocytic stage, differing somewhat in morphology from that of *P. vivax*, was located in the liver (Shortt, Fairley, Covell, Shute and Garnham, *Brit. Med. J.*, 1919, ii, 1006).

THE RÔLE OF MICRO-ORGANISMS IN MAMMALIAN DIGESTION.— Substantial advances have been made in our knowledge on this topic since the matter was last reviewed in this journal (F. Baker, SCIENCE PROGRESS, 1939, **34**, 287). Attention has, for obvious reasons, been concentrated on man and herbivorous animals, and much of the newer information comes from the study of the cow and the sheep. We may distinguish two main aspects of microbial activity in digestion : first, the organisms themselves may serve as food, by

their continuous multiplication producing organic matter which is digested by the host and nourishes it. Since the organisms themselves feed on material ingested by the host animal, they do not increase the total amount of food theoretically available, but they may serve an important function by building up protein from non-protein nitrogen, which the host alone cannot do ; they may also synthesise vitamins absent in the diet of the host but needed by it, particularly vitamins of the B group. Secondly, the organisms may act on carbohydrate in the alimentary canal, creating food that could not be made available by the action of the enzymes of the host : some convert cellulose into substances like starch or dextrin ; others can turn simple carbohydrates into fatty acids which also serve as food (Barcroft, *Proc. Roy. Soc. Edin.*, B, 1945, **62**, 105).

A convenient account of this subject, including most of the current lines of research, will be found in the report of a Symposium on " The Nutritional Rôle of the Microflora in the Alimentary Tract," presided over by Dr. W. R. Wooldridge, and reported in the *Proceedings of the Nutrition Society*, 1945, ·**3**, 195–256. (The " microflora " includes large numbers of Protozoa, which are indubitably animals.) The two rôles of the micro-organisms, as distinguished above, cannot in practice be regarded as distinct. When ingested plant tissues enter the rumen of an ox or a sheep they are submerged in a dense mass of micro-organisms, and microscopic examination will soon show a vigorous reproduction of the organisms, so that they form a continuous covering over the ingested tissues, invading and decomposing them. Synthesis of organic matter is proceeding at the same time as the breakdown of cellulose (Thaysen, *loc. cit.*, p. 195). The same author gives figures indicating that there is a daily synthesis of at least 180 g. of microbial protein in the rumen, and of 235 g. of acetic acid. That the host does in fact use the microbial protein has not been directly demonstrated, but it is indirectly shown by the fact that the organisms undergo marked changes indicative of digestive breakdown during their passage through the intestine, and by the fact that the protozoa and larger bacteria of the rumen contents are usually absent from the fæces (F. Baker, whose work is discussed at several points in the Symposium).

The possibility that Ruminants might maintain normal health and growth on a diet in which the normal dietary protein is replaced by non-protein nitrogen is clearly of great economic importance, provided that such substances can be produced economically. Urea, which might be produced from atmospheric nitrogen, has been tested as a non-protein nitrogen source (J. A. B. Smith, *loc. cit.*, p. 203). Feeding trials have shown that in a properly balanced diet

urea can successfully be used in this way, but readily available carbohydrate, such as starch or simple sugars, must also be present in the diet. The greater part of the protein synthesis is attributed to the masses of micro-iodophile bacteria found in the rumen. It may be that the habit, observed in such non-ruminants as the rat and rabbit, of eating their own fæces, is a method of taking advantage of the microbial synthesis of protein (loc. cit., p. 214).

It is now proved beyond doubt that the adult cow is independent of an exogenous supply of Vitamin B_1, for although this vitamin is required by the animal it is manufactured in sufficient quantity by the bacteria in the alimentary canal. Non-ruminants can similarly be supplied with at least a proportion of their vitamin needs in this way, supplemented, as in the case of protein, by coprophagy. Recent work suggests that vitamin synthesis by his symbionts is important also to man, a fact which may account for certain discrepancies and disagreements in the determination of the normal necessary intake of exogenous vitamins (S. K. Kon, loc. cit., p. 217). The symposium report should be consulted for further details, and for a discussion of such matters as the use by the host of the volatile fatty acids synthesised by the micro-organisms. Another general discussion of the subject took place at a meeting of the Section of Comparative Medicine of the Royal Society of Medicine (Proc. Roy. Soc. Med., 1946, **39**, 802).

PHYSICAL ANTHROPOLOGY. By N. A. BARNICOT, B.Sc., University College, London.

SOME recent papers have directed the attention of anthropologists to the condition known as sickle cell trait or sicklemia, which may prove very useful in tracing the relationships of certain populations. This inherited abnormality of the red blood cells was first described by Herrick in 1910 in a West Indian negro, and since that time it has been found to have a quite high incidence among many of the native peoples of Africa, but to be very rare in Europeans. Herrick's case was associated with a hæmolytic anæmia, and it is mainly because a certain small proportion of the people whose blood shows the trait are also afflicted by this severe pathological condition that a large literature has accumulated on the subject. The point of immediate concern to the anthropologist is the widely different incidence of the trait itself in different peoples, but it will be necessary to refer to the pathological work as well, because, on account of the anæmia, the gene for sicklemia is presumably subject to

negative selection, and this must be taken into account in interpreting the frequency variation between populations. Before quoting some of the figures for the incidence of sicklemia in America and Africa, it will be helpful to consider the nature of the anomaly in more detail ; useful general reviews, with emphasis on the pathology, may be found in Steinberg (*Arch. Path.*, **9**, 876, 1930) and Lewis (*Biology of the Negro*, Chicago Univ. Press, 1942).

A word first about the names ; the term sicklemia for sickle cell trait, although etymologically offensive, has wider currency than the somewhat cumbrous alternatives, dropanocytosis or meniscocytosis. It is important to emphasise again that the term sicklemia does not imply that the subject also has sickle cell anæmia, but means simply that his red cells exhibit this particular anomaly.

If a drop of blood from a person with sicklemia is sealed from air under a coverslip, or in a tube under liquid paraffin, and left for 24–48 hours at room temperature, some of the red cells will be found to have the form of an elongated crescent, resembling a caraway seed, often with long filaments on the points. This transformation, which was investigated carefully by Hahn and Gillespie (*Arch. Int. Med.*, **39**, 233, 1927), occurs only when the oxygen tension of the blood falls to a sufficiently low level ; this happens slowly in sealed blood due to the respiration of leucocytes and of any immature cells which may be present. On readmittance of oxygen the normal biconcave disc shape is resumed. Sickle cells do not therefore occur in the blood-stream of normal persons with susceptible cells, although it is said that they may be detected in some anæmia cases, and it is supposed that the low oxygen tensions in some parts of the vascular bed in these cases leads to sickling which results in blocking of vessels, increased local anoxia and hæmolysis (Murphy and Shapiro, *Trop. Dis. Bull.*, **43**, 581, 1945). Singer and Robin (*J. Am. Med. Ass.*, **136**, 1021, 1948) have described a more rapid technique which permits a diagnosis within 15 minutes ; they add a drop from a culture of *Bacillus subtilis* to the blood, thus speeding up deoxygenation. It is not improbable that some of the reported differences in incidence between populations are due in part to lack of technical uniformity, since it may be necessary to leave some bloods for as long as 72 hours by the slow methods, and cases may thus have been missed. Also the susceptibility of individual cells to sickling varies, so that individual bloods differ in the proportion of sickle cells present after a standard treatment. Ponder (*Hæmolysis and Related Phenomena*, Churchill, 1948) attributes sickling to an abnormality of the ultrastructure of the red cell membrane ; the transformation is preceded by a curious

loss of rigidity of the cell, and does not occur if the formation of reduced haemoglobin is blocked with carbon monoxide. It is not generally agreed whether the sickled cells are more fragile in hypotonic solutions, but it appears that the difference is slight.

It is usually stated that sicklemia is inherited as a Mendelian dominant, but the writer has been able to find very little pedigree data. Huck (*Bull. Johns Hopkins Hosp.*, **34**, 335, 1923) has presented two American negro pedigrees which show the occurrence of the trait in three successive generations, and Beet (*Ann. Eugen.*, **14**, 19, 1949) has recently published two very extensive African pedigrees which are also consistent with the dominant inheritance of the character ; some African family data have also been provided by Trowell (*E. Afr. Med. J.*, **22**, 34, 1945). One of Beet's pedigrees involves nearly two hundred persons. An interesting suggestion made by Beet is that sickle cell anaemia occurs in subjects homozygous for the gene, but more data will be needed to substantiate this.

Figures for the frequency of sicklemia in Africa, and also from two large surveys on American negroes, are reproduced in Table 1.

TABLE I

	Number of Subjects	% Sicklemia.	
West Africa . . .	561	15·5	Evans, 1944
„ „ . . .	5500	12·4	Findlay et al , 1946–47
East Africa . . .	717	17·52	English, 1945
N. Rhodesia . . .	2104	12·4	Beet, 1947
South Africa . . .	403	0·25	Altmann, 1945
Southern States, U S A.	1800	5·5	Sydenstricker, 1932
Tennessee	2539	8·3	Diggs et al , 1923

According to Lewis's summary (1942, *loc. cit.*), of 17 surveys on American negroes the frequency varies from 4·3 to 15·0 per cent., but some of the samples consist of 100 subjects or less. Although differences between regions in the U.S.A. may well exist, due to varying amounts of hybridisation, it appears that the incidence of sicklemia among African negroes is in general considerably higher, with the notable exception of the South African Bantu, determined by Altmann (*S. Afr. Med. J.*, **19**, 457, 1945), which calls for confirmation ; his finding is particularly interesting in view of the divergence of certain South African Bantu tribes in ABO blood group frequency, which was mentioned in a previous review in this series (SCIENCE PROGRESS, **37**, 117, 1949). Apart from Beet's data (*E. Afr. Med. J.*, **23**, 75, 1946, and **24**, 242, 1947), derived from a

few tribes in a comparatively restricted region, the African data reproduced in Table I are very heterogeneous as regards the place of origin of the subjects ; Findlay's sample (*Trans. Roy. Soc. Trop. Med. Hyg.*, **40**, 1946–47) was drawn from the Gold Coast (50 per cent.), French Togoland, Gambia, Sierra Leone, and Nigeria, while English's subjects (*S. Afr. Med. J.*, **19**, 431, 1945) came from a wide area of East and E. Central Africa. Considerable use was made of hospital patients in these surveys, and it is not entirely clear whether this biasses the data, though English says that only half of his sample was from hospital patients, and the sicklemia frequency was the same in this group as in the normal series.

Surveys of the white population in the United States, the largest of which appears to be that of Sydenstricker (*South. Med. J.*, **17**, 177, 1924) on 1000 subjects, revealed no cases of sicklemia. Findlay *et al.* (1946–47, *loc. cit.*) also examined 568 British troops in W. Africa and 188 Syrians without finding a case. While the belief that sicklemia is a very rare character in European populations is probably correct, it is doubtful whether a sufficiently widespread and systematic search has yet been made. The few cases which have come to light were critically considered by Rosenfeld and Pincus (*Am. J. Med. Sci.*, **184**, 674, 1932), who pointed out that particularly in the U.S.A. the possibility of negro ancestry cannot be absolutely excluded, and this explanation may also hold for cases in Greece and Sicily. There is also a possibility that another inherited condition, namely thalassemia (Cooley's anæmia), in which the shape of the red cells is abnormal, may sometimes have been mistaken for sickle cell anæmia, since the former has been found chiefly in persons from the Mediterranean countries. Because European sicklers are generally detected only when the condition is associated with anæmia, there may in fact be a wider distribution of the trait itself, but this could only be determined if surveys, comparable to those of serological characters, were undertaken for anthropological purposes. As far as the writer is aware, there are no data on the incidence of sicklemia in the mongoloid peoples, the peoples of Oçeania, or indeed any groups other than caucasoids and negroes, and it is to be hoped that the question will receive further attention.

The figures already quoted for negro peoples in Africa come mainly from heterogeneous samples, but some interesting information on differences in tribal incidences has recently been published by Lehmann and Raper (*Nature*, **164**, 494, 1949). Using the rapid technique of Singer and Robin these workers examined 24 tribes in the region of the great lakes. Their results, which they classified, according to the language groups, Hamitic, Nilotic and Bantu,

cannot be quoted in full, but some of the most interesting of them are reproduced in Table II.

TABLE II

Language Group.	Tribe.	Number of Subjects.	% Sicklemia.
Hamitic	Bahima	166	2·4
	Suk	128	3·9
	Karamojong	156	3·2
	(Teso)	416	(17·8)
Nilotic	Lango	278	27
	Acholi	141	27
	Jaluo	130	28
	Alur	114	25
Bantu	(Baamba)	140	(45)
	Basoga	241	29
	Baganda	740	19
	(Banyaruanda)	496	(8)
	(Bairu)	139	(2)

The Baamba, who live on the slopes of Mt. Ruwenzori over towards the Congo forests, show the highest frequency ; they are described as pygmoid, and data on true pygmy peoples who are, however, often considerably hybridised with Bantu tribes (SCIENCE PROGRESS, **37**, 117, 1949) would be interesting. The lowest frequencies occur among the Hamitic speakers, and the Bahima, for example, often have markedly caucasian facial features ; the more negroid, agriculturalist Teso, however, from the east of Lake Kioga, have frequencies which approach the Bantu speaking Baganda and Basoga who live to the south of the lake. The low frequencies in the Banyaruanda and Bairu may be due, as the authors suggest, to their closer contacts with the Bahima, whereas the Basoga are more remote from such influence. Many of the Nilotic peoples are tall and linear in build and are usually considered to comprise a distinct physical type. It will be noted that the figures for tribes which are considered to be more or less remote from the caucasian influence of Hamitic peoples are generally a good deal higher than those given by other workers for West Africa, while people such as the Bahima have lower frequencies than the American negroes. More extensive work in Africa may throw much light on the infiltration of this continent by Mediterranean peoples from the north.

The fact that a certain proportion of sicklers suffer from a hæmolytic anæmia which is incurable and often results in death from intercurrent infection, presents an interesting problem, because a considerable gene frequency must presumably be maintained in

some negro peoples in spite of selection against the trait. Different workers give widely divergent figures for the ratio of persons suffering from sickle cell anæmia to those exhibiting the trait. Muir-Robertson and Findlay (*Trans. Roy. Soc. Trop. Med. Hyg.*, **40,** 435, 1946–47) estimated it as 1/151, while Beet from his results on Bantu children in Lagos put it at 1/25. Trowell (*E. Afr. Med. J.*, **22,** 34, 1945) considers sickle cell anæmia the most severe hereditary disorder in Africa, and states that it accounts for one-fifth of the severe anæmias seen in hospitals. Some error may arise from the fact that anæmias of other kinds, particularly resulting from parasitic worms, are extremely common in Africa, so that sicklemia and anæmia may often be fortuitously associated. Nevertheless anæmia from other causes might perhaps precipitate sickle cell anæmia, so that the resulting condition would be all the more severe. There is some evidence that the frequency of the trait is higher in children during the first five years of life (Beet, 1947, *loc. cit.*), suggesting the early elimination of some individuals carrying the trait, and Beet (1949, *loc. cit.*) has also put forward the tentative view that a deficiency of sicklers in matings of sickler × sickler in his African data may be due to the early death of homozygotes. According to Singer and Robin (1948, *loc. cit.*), the red cells of cases of sickle cell anæmia, using the slow method, sickle more quickly than those of persons showing the trait but no anæmia. There have been attempts to show that sicklemia is more frequent in sufferers from certain diseases, such as leg ulcers, but no definite correlations have yet been demonstrated (Beet, 1947, *loc. cit.*). There are clearly many problems to be solved before a genetical interpretation of human polymorphism for sicklemia can be seriously attempted.

A final point of interest is Synder's report (*Proc. VIIIth Int. Cong. Genetics*, 1949) of genetical linkage between the gene for sicklemia and the MN locus, that is to say that the two loci are situated on the same chromosome. Synder used Finney's method of statistical testing for linkage on family data and found no significant linkage between the sicklemia gene (S) and A–B or Rh blood group loci or with the gene for taste-blindness to Phenylthiourea.

It is perhaps worth while pointing out that, even if it is confirmed that there is linkage between the genes S and M–N, it would not be expected that any association between M or N and sicklemia would be apparent in anthropological data composed of random samples drawn from large populations.

NOTES

Goethe and Science

Goethe was born in 1749, so that last year we were celebrating the bicentenary of his birth. One striking feature of this extraordinary man was his devotion to science : he carried out remarkable studies in botany and anatomy, and published an extensive work on the theory of colour, in which he thought that he had demolished Newton's work on colour, and actually recorded some valuable observations on subjective colour effects. Those who are interested in this aspect of the activity of the great poet will welcome the timely appearance of a second edition of Sir Charles Sherrington's short but deeply instructive study,* which first appeared in 1942. The great physiologist, himself a poet, discusses Goethe's general attitude to natural phenomena and considers critically his actual performance in the various fields to which he devoted attention. For this second edition the text has been completely revised and reset and is so much extended that those who possess the first edition will like to possess this. The name of the author is sufficient recommendation.

Science in Industry (A. J. G.) †

A prefatory note explains that : " The last published Report of the Department was the 23rd, for the year 1937–38. The report now published is the 33rd, for the year 1947–48. The intervening reports, though prepared and formally submitted to Parliament as required by Order of Council, will not be published, but the matter contained in them is incorporated in the present Report."

The first ten pages are devoted to a description of the organisa-

* *Goethe on Nature and on Science.* By Sir Charles Sherrington, O.M. Second edition. [Pp. 54.] (Cambridge : at the University Press, 1949. 2*s.* 6*d.* net.)

† *Annual Report of the Department of Scientific and Industrial Research for the year ending the 30th September, 1948, with a Review of the years 1938 to 1948.* [Pp. 64 and Appendices pp. 39.] (H.M.S.O., Cmd. 7761, August 1949. 2*s.* net.)

tion of the Department, its policy (which may be summarised as the " need for scientific research with a view especially to its application to trade and industry ") and the names of the eminent British scientists on the department's Advisory Council, Research Boards and Committees, and Staff, to whose work and co-operation the Department gives full credit for what has been accomplished.

The actual report (pp. 11–64) can be roughly classified as regards contents into :

The Department's own research activities ;

Co-operative research work with industrial research associations ;

Educational and research grants-in-aid ;

Co-operative and liaison work with other departments, overseas and foreign bodies, with, in conclusion, a short summary of German science at the end of the war and the Department's review of its own position in 1948.

The safeguards adopted to ensure liaison, to avoid overlapping by other departments and bodies and to secure the interest of workers overseas and of industrial organisations are described at length. A chart in future reports might be incorporated to permit of rapid visualisation.

Unfortunately it is not possible within the limits of a brief reviewing note to do more than indicate salient points and comment on some points of policy.

In 1938 the department had in its charge the following research establishments : Geological Survey and Museum ; National Physical Laboratory ; Fuel Research Station ; Food Investigation Organisation ; Building Research Station ; Chemical Research Laboratory ; Radio Research Organisation ; Forests Products Research Laboratory ; Water Pollution Research Laboratory ; Road Research Laboratory. Since then the following have been created : Pest Infestation Research Laboratory ; Fire Research Organisation ; Mechanical Engineering Research ; Civil Engineering and Hydraulics Research.

The old and some of the newly created establishments were busily and profitably engaged during the War on urgent war problems (radar and nuclear fission being notable examples out of many). In this period "short term investigations of obvious and immediate application, and advisory work drawing on stocks of existing knowledge at the expense of longer range and more fundamental researches necessarily had priority." It was also acknowledged that the country had been living on its scientific capital during those six years and that consequently " in the post-war period the urgent need is the necessity for rebuilding and adding to the capital of

scientific knowledge." Elsewhere in the report the issue is equally clearly stated, in that British industry and the British export trade are up against intense competition and that fundamental scientific research and its speedy application to industry are playing and will play a decisive part in the struggle.

Pooling brains and resources has proved to be a profitable line to take, an outstanding example recorded in the Report being the wonderful team-work between Britain, America and Canada in speeding up nuclear fission investigations.

Co-operation with industrial research associations was one of the earliest experiments of the Department and has proved successful. In 1948 the number of associations taking part totalled 40. The Department's assistance was in the form of grants-in-aid, frequently on a pound for pound basis, the round figures in 1947 being :

    Actual grants from the D S I R £800,000
    Actual income raised by Industry   .   .   .   £1,400,000

The original policy that such aid should be withdrawn when each association became self-supporting is now being abandoned by the Department, on the grounds that this type of co-operation should be continued in the national interest. This change of view will require strong supporting arguments, for in 1946 independent research by industrial firms in the U.K. was already of the order of £30 million a year and that only represented less than 1 per cent. of the value of a year's British manufacture.

The Department is fully aware of the shortage of scientifically trained workers and the need for the best scientific brains in the field of scientific industrial research. Financial grants to encourage students at the Universities and also research workers rose from £18,000 in 1945–46 to £200,000 two years later, but this figure, even when supplemented by what industrial firms are spending on the same object, is not sufficient to make a rapid enough impression on the shortage. More money is needed to speed up this important activity. The Government's own efforts to establish an adequate Scientific Civil Service have been disappointing (p. 42) and may remain so until it is recognised that good scientific brains can command the same remuneration as other branches of the Civil Service.

A very readable and ably written section of the Report is that (pp. 62–63) dealing with the summary of what has been done and what is contemplated by the D.S.I.R. Lack of staff and buildings is hampering development. Even with expenditure raised from £3 to £4 million a year, as planned, these disabilities will persist for a number of years. One might suggest that concentration on

solving the most urgent investigations, development of the closest liaison between existing organisations, wherever situated, to prevent overlapping and duplication of effort, thus implementing to the full the dictum that "science has no international boundaries," the perfecting of a complete information and abstracting service, working with existing societies such as the Chemical Society and the Society of Chemical Industry among others, will go far towards producing an efficient departmental scientific machine geared to industry.

In its own sphere the D.S.I.R. could speed up the completion of the 6-in. Geological Survey maps of the U.K. and thus make available the facts on the potential mineral and underground water resources of this country. The present target for completion in thirty years is definitely too slow.

The introduction of co-operative research projects between the Pest Infestation Research Board and the Organisations in the countries where the foodstuffs are grown and shipped require examination if only on the common-sense grounds that it is more economical to kill the pests at source than on arrival, in increased numbers, in the U.K.

As the country imports the bulk of its timber, use should be made of the experience and facilities of the exporting countries to season the timber before shipment, in order to save time, shipping and storage space. Such examples could be added to were it not for the exigencies of space.

The D.S.I.R. rightly stresses the difficulty of applying laboratory results to industrial scale operations. This "gulf" has to be "bridged" and perhaps the plan employed in America is worth copying. There the Agricultural Department's Research Centres at New Orleans, Philadelphia and Peoria are so designed as regards buildings, plant and staff at each centre that the laboratory results can be developed rapidly on the pilot scale. Successful results are published and industry is left to do the rest.

Recent Publications

It is a sign of the times that the Department of Scientific and Industrial Research should see fit to issue a *Prospectors' Handbook to Radioactive Mineral Deposits*, pp. 28 (London : H.M.S.O., 1949, 6d. net). The handbook has been written by Dr. C. F. Davidson, Chief Geologist of the Atomic Energy Division, Geological Survey of Great Britain. After a general introduction, the booklet has chapters on the common radioactive minerals, radioactive mineral deposits, how to test for radioactivity, and the market for radio-

active minerals. No attempt has been made at an exhaustive account ; only those data have been given which are likely to be of value to the field geologist or prospector engaged in searching for and evaluating radioactive mineral deposits.

Up to 1900 the world output of uranium oxide was no more than three tons a year. After radium had been discovered the output rose to about 100 tons. From 1920 to 1940 the output averaged about 350 tons owing to the discovery of valuable deposits in the Belgian Congo and Canada. Today, of course, no production statistics are available for obvious reasons, but Dr. Davidson estimates that world output is now at least some thousands of tons per annum. Let us hope that it will not be put to the catastrophic use we all fear ! This booklet is well written and will fully meet the requirements of prospectors. G. W. T.

British Intelligence Objectives Sub-Committee Overall Report No. 15 * correlates and abstracts the main observations of some 400 reports published by H.M.S.O., and numerous foreign documents, which have been produced or collected as a result of an inspection of German iron and steel plants during the period 1944–47 by British and American experts. It is divided into nine main sections, dealing with blast furnace plant and practice ; production of steel ; mechanical treatment ; foundry practice ; steels, ferro-alloys and hard metals ; heat treatment ; cutting, joining, repairing and fastening ; coating, cladding and bonding ; research and testing. The treatment is critical and comparisons are made between German, British and American practice, and between pre-war and war-time practice. Effects of war-time shortages on technical trends are indicated. Full references to original sources are given, together with a comprehensive index. A. H. C.

A booklet on " Hot-tinning," by W. E. Hoare (pp. 112, with 47 figures), has been issued by the Tin Research Institute, Greenford. This gives practical instructions for the production of hot-tinned coatings on fabricated articles and components. The manufacture of tinplate is not considered. The subjects discussed include : operations and plant ; the tinning of steel, cast-iron, copper and other metals ; tinning with tin-lead alloys ; treatment of tinning shop residues ; methods of determining the thickness and continuity of tin coatings. Particular attention is given to new methods of

* *The Ferrous Metal Industry in Germany during the Period 1939 -1945.* By G. Patchin and E. Brewin. [Pp. 270.] (London : H.M.S.O., 1949. 4s. 6d. net.)

tinning cast-iron, and to procedures for the tinning of " difficult " steels, developed at the Tin Research Institute. A bibliography and list of useful data and conversion factors are included.

<div align="right">A. H. C.</div>

The manufacture of abrasives and grinding wheels is a highly specialised industry which has been built up and developed over the past 40 years by a relatively small number of interested persons. There are, in fact, probably not more than 250 people in this country who would claim an interest, on account of the nature of their employment, in the report * recently issued, prepared by the Ministry of Supply. To these few the subject matter is too brief to be of value and they will perforce turn at once to the original reports and documents listed in the references. Neither is it a document which can be commended to the general reader, who without a knowledge of the " art " would find it, to say the least, difficult to follow. There is, however, one enlightening sentence worth quoting : " . . . technical methods used and the quality of abrasives produced judged by British and American standards was inferior." This might well be called the theme of the report.   C. G. B.

A new monthly publication of the Leonard Hill Technical Group, entitled *World Crops*, edited by Sir Harold Tempany, has recently appeared. It aims to discuss developments not only in actual production but also in the associated realms of soil science, fertiliser production, crop protection, the marketing and processing of crops for food and industrial purposes, and in farm implements and equipment. At the present crucial time, when agricultural production both of food and of raw materials for the manufacture of producer goods lags behind the ever-increasing demand from a rising world population, close co-operation between the many industries concerned, not only in individual countries but at an international level, is vital. Sir John Russell stresses this point in an introductory article welcoming this new journal as a contribution towards this end. The declared objectives of *World Crops* should render the publication of value as a source of information to agriculturists in all branches of the industry, to manufacturers, and to those concerned with administration and the scientific aspects of agriculture.

The first number of this well-produced and well-illustrated publication contains authoritative articles by D. H. Grist on rice produc-

* B.I.O.S. Overall Report No. 26 : *Abrasives, Their Manufacture and Use in Germany during the Period 1939–1945*. [Pp. 22.] (London, H.M.S.O., 1949. 6d. net.)

tion, by Sir Harold Tempany on the menace of the cocoa disease, by Dr. G. W. Cooke on fertiliser placement, and an interesting description of the reclamation of agricultural land on Walcheren, by A. Franke and C. Visser. Other articles deal with various crops, *e.g.* vegetable oils, tobacco, sorghum, with locust outbreaks in South Africa, with developments in agricultural machinery and in agricultural education, and with notes on world markets, meetings and discussions of appropriate organisations.

The annual subscription is 25*s*. for 1 year, 40*s*. for 2 years and 50*s*. for 3 years. A. G. P.

The current volume of the *Annales Biologiques*,* published by the Conseil Permanent International pour l'Exploration de la Mer, contains data on hydrography and plankton in the vicinity of Iceland, in the Faroe-Shetland Channel, the North Sea, Baltic and elsewhere ; but the bulk of the publication is devoted to fish—cod, haddock, hake, whiting, eel, plaice, dab, flounder, sole, megrim, witch, herring, sardine, mackerel and some other less important kinds. Some reference is also made to lobsters, deep-sea prawns and oysters. The *Annales Biologiques* is a useful publication for those interested in marine biology with special reference to fisheries research. G. A. S.

Miscellanea

The 1949 Nobel Prize for Peace has been awarded to the Rt. Hon. Lord Boyd-Orr, F.R.S.

Prof. E. N. da C. Andrade, Quain professor of physics in the University of London, has succeeded Prof. E. K. Rideal as resident professor and director of the Davy Faraday Research Laboratory in the Royal Institution.

Sir Reginald Stradling, C.B., F.R.S., chief scientific adviser to the Ministry of Works, has been appointed dean of the Military College of Science, Shrivenham, in succession to the late Prof. C. H. Lander.

Mr. H. M. Garner, principal director of scientific research (air) in the Ministry of Supply, has been appointed chief scientist to the Ministry of Supply in succession to Sir Ben Lockspeiser.

Prof. K. Mather, professor of genetics in the University of Birmingham, Prof. S. Zuckerman, professor of anatomy in the Univer-

* Vol. IV for 1947. [Pp. 152, with numerous figures.] (Copenhagen : A. F. Høst & Sons, 1949. Kr. 18.00.)

sity of Birmingham, and Prof. G. F. Marrian, professor of chemistry in relation to medicine in the University of Edinburgh, have been appointed members of the Agricultural Research Council in succession to Prof. T. G. B. Osborn, Sir John Simonsen and Mr. W. J. Wright, whose terms of office have expired.

We have noted with great regret the announcements of the death of the following scientific workers during the quarter : Dr. G. S. Baker, O.B.E., the first superintendent of the William Froude Laboratory, National Physical Laboratory ; Sir Rowland Biffen, F.R.S., emeritus professor of agricultural botany in the University of Cambridge ; Mr. William Binnie, past president of the Institution of Civil Engineers ; Dr. James A. Bowie, principal of the Dundee School of Economics ; Prof. C. L. Fortescue, O.B.E., emeritus professor of electrical engineering, Imperial College of Science and Technology ; Prof. M. Greenwood, F.R.S., emeritus professor of epidemiology and vital statistics, London School of Hygiene and Tropical Medicine ; Mr. A. H. Hall, formerly chief superintendent of the Royal Aircraft Establishment, Farnborough ; Prof. G. H. Henderson, O.B.E., F.R.S., professor of mathematical physics in Dalhousie University, Halifax ; Prof. August Krogh, For.Mem.R.S., emeritus professor of zoophysiology in the University of Copenhagen ; Dr. A. P. Laurie, formerly principal of the Heriot-Watt College, Edinburgh ; Prof. W. B. Morton, emeritus professor of physics in Queen's University, Belfast ; Mr. C. E. Muriel, conservator of forests (Bengal) during 1910–16 ; Prof. P. E. Newberry, O.B.E., formerly Brunner professor of Egyptology in the University of Liverpool ; Mr. H. O. Newboult, fellow and mathematical tutor of Merton College, Oxford ; Sir Edwin Pascoe, director during 1921–32 of the Geological Survey of India ; Sir Robert Pickard, F.R.S., formerly director of research, British Cotton Industry Research Association ; Dr. E. W. Posnjak, formerly of the Geophysical Laboratory, Carnegie Institution of Washington ; Prof. Edwin B. Powers, professor and head of the Department of Zoology, University of Tennessee ; Prof. S. H. Reynolds, emeritus professor of geology in the University of Bristol ; Prof. B. Sahni, F.R.S., professor of botany in the University of Lucknow ; Sir Frank Stockdale, G.C.M.G., C.B.E., vice-chairman of the Colonial Development Corporation ; Dr. Frank Thone, biology editor of *Science Service*, Washington.

The *Bell Laboratories Record* for August 1949 contained a number of articles of general interest. First we may note a description, by A. V. Hollenberg, of a new method for amplifying radio-

frequency signals. The device, known as the double-stream amplifier, consists of an evacuated tube, a foot or more long, through which two concentric streams of electrons pass from two axially separated concentric ring-shaped electrodes at one end of the tube to a collector at the other end. The two streams are given different velocities by accelerating grids and are held to cross-sections about equal to those of the electrodes by a longitudinal magnetic field produced by a current in a coil wound on the outside of the tube. Inside the tube and coaxial with it are two short wire helixes. One, just beyond the grids, carries the input signal and modulates the electron streams ; the other, at the far end of the tube, picks up the amplified output signal. No simple physical explanation of the fact that the modulation of the double stream at one end of the tube increases in amplitude as the electrons travel through it is, as yet, available. That such amplification should occur was deduced mathematically in the course of a theoretical study of another phenomenon and the experiments described by Dr. Hollenberg had, as their first object, the verification of this deduction. Amplification occurs only when the current densities in the two streams exceed a minimum value and increases, with increase of the current densities, to a limit of 27 decibels per unit velocity separation (ratio of the difference of the two stream velocities to their mean) per wavelength in the distance between the helixes. The gain varies slowly with signal frequency and in the experimental tube, about 16 wavelengths long, had a value of 30 db. at 200 megacycles per second. It rose to a maximum of 33 db. at 250 mc./sec. and had fallen again to 30 db. at 310 mc./sec.—a working range of 110 mc./sec. It is hoped that the amplifier will prove useful in work with very short microwaves.

A second article, by W. P. Mason, describes the use of ceramics fused from barium titanate crystals as transducers for changing electrical to mechanical energy at ultrasonic frequencies. They have several advantages over quartz or Rochelle salt : they are isotropic and so will act efficiently over their entire area ; they can be made of any size or shape so as to give, for example, a focused beam ; the dimensional changes produced by electric fields can be made much greater than is possible even with Rochelle salt and their properties do not vary greatly with temperature. If pure barium titanate were used a D.C. biasing voltage would be necessary. To avoid this the material is mixed with 4 per cent. of lead titanate and polarised by allowing it to cool from a temperature above the Curie temperature in a strong electric field. The presence of the lead " impurity " locks the ferroelectric axes and so makes the

remanent polarisation permanent. Transducers prepared in this way have been made to radiate 100 watts per sq. cm. continuous acoustic power.

In a third paper, W. Koenig describes the advantages of plotting acoustic characteristics against frequency with a linear scale for frequencies up to 1000 cycles per sec. and a logarithmic scale for frequencies greater than 1000. He recommends that the range 0–1000 be represented by 2 in. on the frequency axis, divided as usual into tenths of an inch and that this be followed by $4\frac{1}{2}$ in. divided logarithmically to represent the range 1000–10,000. On graphs plotted to this scale the length of any band of frequencies is roughly proportional to the response of the ear to that band. An entirely linear scale contracts the important 0–1000 band, while an entirely logarithmic one gives it too great a prominence. With the new ruling the distance corresponding to the range 900–1000 is very nearly the same as that representing the range 1000–1100 so that the transition is "smooth." There is also the additional advantage that many of the characteristics of the ear give nearly linear graphs, for example the number of nerve endings in the basilar membrane which respond to frequencies below any assigned maximum— 10 per cent. below 400, 20 per cent. below 750, 40 per cent. below 1500, 75 per cent. below 5000 and 90 per cent. below 10,000.

The use of a barium titanate ceramic to replace quartz as a transducer in the ultrasonic frequency range has been mentioned above. In the *Bell Laboratories Record* for July 1949, W. Zeigler describes the use of ethylene diamine tartrate crystal units to replace quartz crystal units in the electric wave filters of broadband carrier telephone systems. This particular substance was selected after long research undertaken in anticipation of a shortage of natural quartz of suitable quality. Zeigler's article does not indicate the reasons for choosing it, but describes in detail how suitable plates are cut from the crystals and how they are prepared and mounted for use. The procedure is of considerable interest since the plates are fragile, soluble in water (the final adjustment of the resonance frequency can be made by wiping with a damp cloth), and have coefficients of linear expansion which vary with direction from $- 20$ to $+ 160 \times 10^{-6}$ per deg. F.

ESSAY REVIEWS

THE FOUNDATIONS OF SCIENCE. By Herbert Dingle, D.Sc.,
D.I.C., A.R.C.S., Professor of History and Philosophy of Science in the
University of London, University College. Being a Review of **The
Logic of the Sciences and the Humanities**, by F. S. C.
Northrop. [Pp. xiv + 402.] (New York : The Macmillan Company ;
London : Macmillan & Co., Ltd., 1948. 33s. 6d. net.)

The philosophy of science—*i.e.* the understanding of the ideas or
postulates or assumptions or whatever they may be on which
scientific theory is ultimately based—is a subject of growing import-
ance and interest, not only because of its bearing on the question
of the validity of science itself but also because of its relevance to
other kinds of human endeavour which are becoming more and more
clearly recognised as having a scientific aspect. A work on the
subject which attempts to treat it really fundamentally, such as that
of Professor Northrop, therefore demands serious attention. The
book is long and covers a wide field. In this essay I shall be con-
cerned mainly with the basic notions on which the remainder rests.

Professor Northrop begins by pointing out that all knowledge
is founded ultimately on "pure fact," which may be defined as
"that which is known by immediate apprehension alone " ; " it is
that portion of our knowledge which remains when everything de-
pending upon inference from the immediately apprehended is
rejected." It precedes description and even naming. A sensation
of blue is an example, but the moment we call it " blue," merely
to denote it, we have advanced a step beyond the original datum.
The whole field of pure fact is called " the differentiated æsthetic
continuum "—*continuum* because what we later call sounds, sights,
pains, etc., are all crowded together in it ; *æsthetic* because rational
apprehension is absent (the word does not imply the appreciation
of the fact as beautiful or anything of that kind) ; and *differentiated*
because apparently Professor Northrop holds that the distinction
between, say, a sight and a smell is primary, is given, and is not made
by subsequent reflection.

The first stage in all rational thought is the giving of names to
the pure facts ; such names are called " concepts by intuition."

" A concept by intuition is one which denotes, and the complete meaning of which is given by, something which is immediately apprehended." The name " differentiated æsthetic continuum " is the primary concept by intuition ; all others (*e.g.* blue) are derived from it by subtraction of something.

The next stage is the formation of " concepts by postulation." The meaning of such a concept " in whole or part is designated by the postulates of some specific deductively formulated theory in which it occurs." This sounds more advanced than it necessarily is. Our ordinary, commonsense world, consisting of other persons, tables, chairs, etc., is a set of concepts by postulation and deductions from them. The naïve realist takes these things as initial data, but it is essential to Professor Northrop's view that they are a possible, but by no means necessary, means of formulating the relations that we find to exist among conceptualised constituents of the continuum. The meaning of the word " chair " is not given by pointing to a chair, but by indicating its place in a description of this whole commonsense world, and it includes, for example, the notion that the chair goes on existing when no-one is perceiving it. Hence its meaning is designated by the postulates of a theory of material objects distributed in space and time. The world of the modern physicist is another set of such postulates and deductions—or perhaps several sets in so far as the different branches of physics are not yet wholly correlated with one another. The meaning of the word " electron " is designated by the postulates of the physical theory in which it plays a part.

The first stage in a scientific enquiry is to designate the facts with which we are concerned, *i.e.* to formulate the relevant postulates by intuition. The second stage is concerned with the classification of these concepts. This is called the " natural history " stage of enquiry. Biology almost up to the present day and Aristotelean physics are examples of sciences in the natural history stage. The third stage involves the formulation of concepts by postulation, and therefore the use of a " deductively formulated theory " and the use of formal logic. This was started in physics by Galileo and Newton. It requires a complete break-away from the natural history stage of enquiry.

This break-away is not always evident, however, especially if, as sometimes happens, the primitive concepts by postulation of the deductive theory are made identical with concepts by intuition made immortal (*e.g.* a concept of blueness, which is blue made timeless). In such cases the theory can be tested directly by observation. Professor Northrop seems to regard the commonsense world as being

of this type, and to conceive of the " natural history " stage of science as being describable in terms of commonsense objects instead of pure concepts by intuition, but he is a little obscure on this point. The basic scientific concepts of the third stage of enquiry, however, are quite independent of concepts by intuition. For example, the existence of the electron can never be determined by direct observation, not because of experimental difficulties but because the electron is defined in terms of pure concepts by postulation, having in themselves no relation to concepts by intuition.

If the postulates—and therefore the succeeding theorems—of a deductively formulated theory are independent of observation, how can the theory be tested by observation ? Professor Northrop answers that we must connect it with concepts by intuition by means of an " epistemic correlation," *i.e.* " a relation joining an unobserved component of anything designated by a concept by postulation to its directly inspected component denoted by a concept by intuition." This correlation must be set up, and its termini chosen, presumably, by the free act of the propounder of the theory. It always, however, connects some concept by intuition with a theorem deduced from the concepts by postulation of the theory, never with the postulates themselves. Hence the validity of those concepts, though it may be disproved by observation, can never be finally established unless we can show that no other concepts could possibly lead to the theorem which is verified by observation.

Such, in outline, is Professor Northrop's description of the foundations of science. I have, of course, omitted some of the finer analysis and I have no space to discuss the application which he makes to art, economics, and so on, of ideas arising from this mode of approach. I would like, however, to comment on the general view.

I have found it particularly interesting because it conforms more closely to what I consider the most valuable way of approaching these fundamental problems than any other of which I know. It is so common to find writers on these subjects beginning with an arbitrary assumption—be it the existence of an " external world " or of " other people " or of " mind " or what not—that one cannot be too thankful for an author who begins not by assuming something but by describing as faithfully as he can what he cannot help knowing. I attempted the same thing some years ago in a book * which, from the many points of resemblance, I felt sure that Professor Northrop must have read. He makes no reference to it, however, and since he makes some oversights which I do not think would have

* *Through Science to Philosophy* (Oxford University Press, 1937).

been possible had he done so, I must conclude that it has escaped him. I will try to indicate some of these, but it is a distasteful task to dwell on what one considers defects and I would wish first to indulge the pleasure of saying how much I have enjoyed reading the book and profited from it—despite the truly terrible Preface, which whoever reads will need all his will-power to carry him further. Professor Northrop's line of thought indicates in the clearest manner the danger of confusing conceptions such as electrons with small material objects—a very real danger, since many even of our leading physicists still make this error. His insistence that the ordinary commonsense world is not given to us as an initial datum but is a rational construction made for one purpose and not necessarily suitable for others is most timely. Excellent also is the implication that, since in the æsthetic continuum there is nothing to mark off what we later call our " subjective feelings " from " sense-data," there is no reason to suppose that the former are not as amenable to scientific treatment as the latter. The whole manner of approach, indeed, puts one in the best possible position to deal not only with the problems peculiar to present-day science but also with the permanent problems connected with the significance of science in itself and in its relation to other human activities.

It is therefore all the more surprising that Professor Northrop should have left out of account some of the most important factors of the situation with which he grapples. The first is time ; this, which forms the central problem of scientific philosophy, is almost completely overlooked. We are thus in a difficulty at the very beginning. Is the æsthetic continuum what, in the later rationalisation of it, we call an " instantaneous presentation " or does it include the whole of our awareness, past and present, which only later we arrange in a time order ? If the latter, how do we make the arrangement—by concepts of intuition or of postulation ? How far are they at our disposal ? If it is an instantaneous awareness that we start with, are those differentiations that later we are to call " memories " distinguished in any way from those which we are to say we were actually experiencing at that instant ? If not, by what process do we thereafter distinguish them ? I am not here suggesting answers to these questions but simply pointing out that they inevitably arise and that Professor Northrop gives us no clue as to how to answer them. Consequently we are completely at sea at the very beginning ; we do not know whether it is " pure fact " that some experiences are past and some present, that some are long past and others recent, that A happened before B and not after, that the experience which at this moment makes me shudder is not happening

now but is a memory of something that has happened—or whether all these distinctions are superposed on fact by subsequent rationalisation and are therefore subject to alteration when a new theory takes the place of the present one.

Another fundamental omission is the necessary complement of the æsthetic continuum—namely, what I may unsatisfactorily call "principles of reasoning." No name is satisfactory because, like the continuum itself, it cannot be named without making questions possible, whereas what I mean is unquestionable. When a logical argument is set out in minute detail we find that we are able—nay, forced—to admit that each successive proposition is entailed by the previous ones, and this is as essential to the construction of science as is the "pure fact" provided by the continuum. Professor Northrop defines pure fact as "that portion of our knowledge which remains when everything depending upon inference from the immediately apprehended is rejected." But these principles of reasoning also remain, otherwise we would have to stay in the continuum and no inferences would be possible. An awareness of blue is just what it is ; it does not "follow from" anything or "entail" anything, but stands alone, and a mere multiplicity of such awarenesses allows of no advance towards the goal of a "deductively formulated theory." That becomes possible only when one is able to perceive that some steps are necessary, some permissible, and some prohibited.

Of course, in a sense the need for these principles of reasoning is implied in Professor Northrop's treatment, but the failure to recognise and explicitly to acknowledge them leads him into some confusion, particularly in his treatment of his "epistemic correlations." Let us consider the course of science according to Professor Northrop's description. We start with pure fact—the æsthetic continuum. We then name the constituents of this continuum, and the names constitute the concepts by intuition. We next form concepts by postulation by means of which we can construct a logical theory which we have to correlate somehow with pure fact. We can then say that we have "rationalised" experience, *i.e.* expressed it as a logically connected system instead of as a mere aggregate of differentiations in a non-rational continuum, and this is what science aims at doing.

Now where, in this process, do we find the need for a bridge (for what Professor Northrop calls an "epistemic correlation") to connect successive stages ? If we recognise that we start with two independent things—pure fact and principles of reasoning—we can answer at once that the bridge must connect the realm of pure

experience uncontaminated by reason with the realm of concepts, for in the former we cannot use our principles of reasoning and in the latter we can. How, then, is it possible for a mere awareness of blue to become something which can entail or follow from something else ? This is a really fundamental question, corresponding in this way of approaching the philosophy of science to the Cartesian problem of how contact was possible between *res extensa* and *res cogitans*, or the common present-day problem of body and mind, which Professor Northrop briefly discusses without perceiving the vital core of it.

Again I am not proposing to discuss this question but merely pointing out its existence, but before dealing with Professor Northrop's treatment I might point out under what a disadvantage he places himself by ignoring time. For one quite indispensable step in the passage from experience to concept is provided for us automatically by the passage of time. An immediately felt experience is essentially non-rational, but no sooner is it felt than it has become past—no longer vivid but eternal and immutable, a possible object of leisured contemplation, and as such at least in a position to become conceptualised, which cannot be said of the experience in its immediacy. However, in Professor Northrop's treatment the gap which must be bridged by the epistemic correlation must be either that between (1) pure fact and (2) concepts by intuition, or that between (2) concepts by intuition and (3) theory involving concepts by postulation. But when we try to find which it is we find nothing but confusion, simply because Professor Northrop has not clearly visualised the two distinct elements of experience and reason.

We read first that an epistemic correlation joins " an unobserved component of anything designated by a concept by postulation to its directly inspected component denoted by a concept by intuition " (*i.e.* it joins (2) and (3).) But immediately afterwards we read that it " joins the æsthetic component of a thing to its theoretic component " (*i.e.* it joins (1) to (2) or (3).) Where are we ? And what is the " thing " which has these two " components " ? It looks like a *Deus ex machina*. Let us turn to an example to get more light. We read that an epistemic correlation occurs in connection with the general theory of relativity. The " theoretic component " here consists of ten variables in a tensor equation, for, says Professor Northrop, mathematical considerations indicate that laws independent of the observer's circumstances must be of tensor form (incidentally, that is not so ; laws of tensor form are independent of the observer's circumstances, but that is not the same thing). This is certainly (3). The " empirical epistemic correlates " of these

variables are then given as " potentials." But what are potentials ? They are hardly pure fact, nor would our young students of physics recognise them as concepts by intuition. They are unavoidably (3), so that the epistemic correlation connects (3) with (3). So now what do we do ?

The fact is that, again owing to his lack of perception of the fundamental distinction between pure fact and principles of reasoning, Professor Northrop has not clearly realised even what he means by the passage from (1) to (2). He describes it as merely giving names to the differentiations. But what names ? If every differentiation has a unique, completely independent name, then indeed you are still on the hither side of the gap between experience and rational correlation, for you have merely substituted the experience of seeing or hearing a name for the experience represented by it. But if you give the name " green " to a differentiation which later is to be described as the colour of a leaf, are you to call the adjacent differentiation (another leaf) " green " also ? If so, then some element of ratiocination has come in ; you have recognised *similarity*, and so begun a classification, which is a stage in correlation. The process of naming must therefore be specified somewhat carefully, but Professor Northrop does not discuss it ; he apparently takes it to be so simple that comment is unnecessary.

It should be remarked that if, as I have indicated is possible, he envisages the " natural history " stage of scientific enquiry as one in which the data are regarded as commonsense objects and not pure concepts by intuition, then another bridge is necessary to connect such objects with the deductively formulated theory. The epistemic correlations sometimes seem to have this function. I think, however, that although historically the natural history stage has occurred, it can be left out of the *logical* line of development of science, because the later stage is independent of it. Modern physics, for example, effectively began with Galileo, and whatever debt it owes to previous work might very well not have been incurred.

I have little space for the application of this philosophy to ethical and religious questions, though it is a prominent concern of the author. Perhaps this is just as well, for this part of the book is far inferior to the earlier part. Briefly, Professor Northrop holds that ethical and religious ideas rest on partial philosophies of science. Locate their foundations and subsume them in the latest complete philosophy of science, and a universal ethical and religious code will result. Alas, it is not so simple ! Whatever your view of the " cosmic law," you may always, like Huxley, assert a " moral law " that opposes it. When you have proved what is good by the most

complete deductively formulated theory, someone—a Jesus or a Mahomet or a Nietzsche, knowing nothing of science—will announce that it is bad, and a new doctrine will arise. It is all very tiresome, but it is the way things are. And the reason is that ultimately ethics cannot be built on the philosophy of science, but the philosophy of science must rest on an ethical judgment. It is sensible to ask if it is good to pursue the philosophy of science, and a negative answer would not automatically brand the speaker as either dishonest or insane : it is not sensible to ask if it is the philosophy of science to pursue the good. Professor Northrop claims that his prospective universal ethics will lead to peace, but what if peace is bad, as some moralists assert ? Professor Northrop does what he professes to abhor—he *presupposes* that peace is good. He has overlooked something else besides the principles of reasoning, but whereas the latter oversight makes, say, a 10 per cent. cut in the effectiveness of his philosophy of science, the former makes at least a 90 per cent. cut in the effectiveness of his philosophy of ethics.

There is excessive repetition in the book—evidently because it is an insufficiently edited collection of separate addresses. The writing is distinguished by a limited vocabulary—the reader will fervently hope never to meet the word " attendant " again in his life ; " attendantly " he is scarcely likely to encounter--and one feels that the pace could sometimes be accelerated with advantage ; but one common and supreme fault the writing has not—it is not ambiguous. For this outstanding virtue all must be forgiven. For a Professor of Philosophy Professor Northrop has an amazingly wide and accurate knowledge of science. The chief exception is thermodynamics, his account of which is conspicuously inaccurate and illogical. This, however, is a trifle. No blemishes can obscure the fact that he has found the only unassailable foundation for a philosophy of science, and it is greatly to be hoped that he will give his line of thought the further consideration it requires and deserves.

THE STUDY OF LICHENS. By C. T. INGOLD, D.Sc., F.L.S., Professor of Botany in the University of London, Birkbeck College. Being a review of **Natural History of the Danish Lichens** by Olaf Galløe, Ph.D. Parts I–VII published, Parts VIII–X to appear later. (For number of pages and illustrations see " Books Received " list, p. 206.) (Copenhagen : Einar Munksgaard, 1927–48. Dan. Kr. 40.– per Part.)

THE nature of the association of fungus and alga that constitutes a lichen has given rise to considerable academic discussion. Does the fungus parasitise the alga ? Does the alga live a life of beneficial

slavery (helotism) ? Is it an example of symbiosis—the " living together *for* mutual good " of the hard-boiled teleologist ? The relative merits of parasitism, helotism or symbiosis can be left safely to the academic botanist who can usually count the lichens he knows in the field on the fingers of one hand. It is quite clear that the lichen fungi live at the expense of the associated algæ and the name given to the association is immaterial. Apart from the discussion of lichens as dual organisms, they have received scant attention at the universities. This is a very great pity. Ecologists are becoming increasingly aware of the importance of a knowledge of the taxonomy of lichens and, since ecology has become such a popular branch of academic Botany during the past quarter of a century, we may look forward to lichens receiving considerably more attention in the future in university courses. For this reason alone the appearance of a major work on the taxonomy of lichens is very welcome.

Dr. Olaf Galløe has devoted a life-time to lichenology. His work on the *Ecology of Danish Lichens* was published over forty years ago, this was followed by the *Lichen Flora and Lichen Vegetation of Iceland* in 1920, and the present monumental work will no doubt be considered his greatest contribution to his chosen subject. Part I of this work was published in 1927 and subsequent volumes were issued from time to time until 1939 when Part VI appeared. Then came the interruption of the World War, so that publication of Part VII was delayed until 1948. The work is not yet finished— there will be three further volumes—and it is greatly to be hoped that nothing will happen to delay the completion of this important work. The parts published so far are purely taxonomic, but the author indicates that the final volume will be concerned with " a survey of the taxonomy and general natural history of Danish lichens."

Dr. Galløe's work is in no way a compilation, for it is entirely original. Although it will ultimately deal with all known Danish species, the author is at pains to point out that it is not a " Flora " and includes no data on distribution. He has taken a strong and individual line in dealing with species. He says " The description of species is based on *one single individual* which I describe morphologically and anatomically in full detail." Sometimes, in variable species, he describes several individuals, but each separately. His attitude to nomenclature may shock some museum taxonomists, but it is rather refreshing. He remarks : " I have first examined the single specimen as carefully as possible, and then I have endeavoured to find in the literature . . . as detailed a description as possible. . . . If there I have succeeded in finding a good description which

seems to correspond minutely to the individual examined by me, I have given it the name used in the work quoted. . . . I have entirely omitted any discussion of synonyms." It is, perhaps, the natural attitude of the worker interested primarily in the organisms he is studying rather than in the ramifications of the literature of the subject.

All Danish species of lichen are illustrated and all the figures are original. Most of the plates are of very high quality. Many are in colour and these, though restrained, are often of surprising beauty. The author's success in depicting the surface texture of a lichen thallus is truly amazing.

In lichens chemical tests have been widely used as an aid to identification, but Dr. Galløe does not view them with favour (except perhaps the KOH test), considering them to be somewhat capricious.

Part I deals with the genus *Lecidea*, but also contains a brief and rather extraordinary discussion on the evolution of lichens. It is clear that Dr. Galløe's views on evolution are somewhat heterodox. Perhaps this can best be illustrated by a brief quotation : " It has been thought that there may exist a kind of psychic condition which co-operates in the development of species. . . . I personally have no doubt that psychic processes take place side by side with material processes though there is no likelihood of this ever being proved. I . . . am most inclined to the view that the faculty present in the organism of choosing in many cases between several possibilities is of a psychic immaterial nature." One cannot help feeling that few botanists will agree with Dr. Galløe in this. It is more usual to find a botanist who thinks even of himself as " a being who moves in predestinate grooves, not even a bus, just a tram," and who would certainly not allow more freedom of choice in a lichen !

However, this valuable work is not to be judged on the philosophical views of its author. The real question is : will it help the serious student to identify the lichens he finds ? There can be little doubt that the answer is in the affirmative.

The British student wishing to identify a lichen will turn in the first instance to Lorrain Smith's excellent British Museum Monograph, but Dr. Galløe's work will be of considerable value to him in checking a determination, especially as, in all probability, the majority of the Danish species also occur in this country. The ten parts of the *Natural History of the Danish Lichens* should certainly find an honoured place in the botanical section of the libraries in all universities and museums.

REVIEWS

MATHEMATICS AND MATHEMATICAL PHYSICS

Pfaff's Problem and its Generalisations. By J. A. Schouten and
W. v. d. Kulk. [Pp. xvi + 542.] (Oxford: at the Clarendon Press,
1949. 50s. net.)

When the conditions of integrability of a total differential equation

$$\omega_\lambda \, d\xi^{\lambda'} = 0 \qquad (\lambda = 1, \ldots n)$$

are not satisfied, there is no single equivalent integral equation. However,
investigation, initiated by Pfaff in 1814, has shown that a set of equivalent
integral equations exist and their determination is Pfaff's problem in its
simplest form.

Geometrically, the above Pfaffian equation represents an E_{n-1}-field (that
is, an $(n-1)$-direction at every point) in the geometric manifold X_n. If
it is completely integrable, these E_{n-1}'s are tangent to a simply infinite
system of X_{n-1}'s in X_n. Otherwise, there are X_m's $(m < n-1)$ in X_n
whose tangent E_m at every point lies in the E_{n-1} at the point. The simple
Pfaff's problem consists of the determination of all such enveloped X_m's.

The problem has since been generalised and this book contains a detailed
survey of our present knowledge of the subject as well as the results of the
authors' own recent research. The methods of tensor calculus are used
throughout and the first chapter gives an account of the notation used.
Readers not familiar with Prof. Schouten's work on differential geometry
will find this a very useful introduction. The second chapter deals with
the analytical background.

Given a system of $n - p$ linearly independent Pfaffian equations, which
represents an E_p-field in X_n, two problems will arise. The " outer " problem
requires the determination, for the minimum value of m $(m > p)$, of the
enveloping X_m's (whose tangent E_m at every point contains the E_p of the
field). This is developed in Chapter III. The " inner " problem, a general-
isation of which is discussed in Chapter VIII, is to determine the X_m's
$(m < p)$ enveloped by E_p's of the field for the maximum value of m.

In Chapter IV the simple Pfaff's problem is considered and the classifica-
tion of Pfaffians $\omega_\lambda d\xi^\lambda$ is undertaken. This also is generalised in later
chapters.

Altogether, the scope of the book is comprehensive and it is likely to
be the standard work on the subject for a long time. It will, of course, be
indispensable to the specialist in the theory of linear differential equations
and their applications. Others may not find it easy to read. There are,
however, exercises at the end of most chapters and suggestions are given
for their solution. There is also a useful bibliography.

<div align="right">R. S. Clark.</div>

Cardinal Algebras. By ALFRED TARSKI. With an appendix by BJARNI JÓNSSON and ALFRED TARSKI. [Pp. xii + 326.] (New York and London : Oxford University Press, 1949. 80s. net.)

THIS is a book for mature mathematicians which, roughly speaking, reveals the results of an intensive study of the theory of cardinal numbers from the point of view of abstract algebra which was begun some twenty years ago by Prof. Tarski in collaboration with A. Lindenbaum. It will certainly be an inspiration to workers in both fields.

The arithmetic of infinite cardinals due to G. Cantor differs in many respects from the familiar arithmetic of integers. For instance, every infinite cardinal a satisfies the equation a + a = a, and infinite sums are always significant. Another difference is that the cancellation law " a + c = b + c implies a = b " does not hold : for instance, $\aleph_0$ denoting the smallest infinite cardinal, we have $1 + \aleph_0 = \aleph_0 = 2 + \aleph_0$.

It was recognised that a considerable number of the theorems obtained could be deduced from a few basic ones. Consequently it was natural to take the properties expressed by those theorems as axioms defining algebraic systems which Tarski calls cardinal algebras. The Cantorian algebra of cardinal numbers is definitely only a special case of cardinal algebras, for, for example, infinite elements in a cardinal algebra do not necessarily satisfy a + a = a and a cardinal algebra is not necessarily well ordered.

The first part of the book is concerned with the arithmetic of cardinal algebras ; the second with the construction of cardinal algebras ; the third with the relations between cardinal algebras and other algebraic systems such as semi-groups, lattices, and Boolean algebras. An appendix, written in collaboration with B. Jónsson, discusses cardinal products of isomorphism types.

JOHN TODD.

From Euclid to Eddington : A Study of Conceptions of the External World. By Sir EDMUND WHITTAKER, F.R.S. [Pp. x + 212.] (Cambridge : at the University Press, 1949. 15s. net.)

MATHEMATICAL physics in this country is fortunate in having two exponents who must have discovered the secret of eternal youth ; and if Bertrand Russell is one of them, surely the other must be Sir Edmund Whittaker ! In this book he covers rapidly and with a masterly touch the history of mathematical physics from the earliest Greek ideas on geometry to Eddington's theories of the constants of Nature, taking in his stride non-Euclidean geometry, special relativity, thermodynamics, electromagnetic theory, general relativity and gravitation, quantum theory and statistical mechanics. And it is written in the easy style and with the cheerful zest of a man who finds each new idea fascinating and who looks forward eagerly to the next development. Naturally, when so much ground is to be covered, brevity is essential and the reader must supply much of the background in order to appreciate the book properly. Formulæ are quoted but there is no space for proofs and this, curiously enough, makes the chapter on Eddington's work rather disappointing. Though it contains an illuminating account of Eddington's ideas and of his astonishing results in calculating the constants of physics, yet we are given no clue as to whether or not Whittaker agrees with the mathematical arguments by which Eddington reached his conclusions. But this blemish, if blemish it is, is compensated

for by many excellencies, two of which appealed particularly to this reviewer : Whittaker's " debunking " of the term " curvature of space " and his inclusion of special relativity under classical physics, where it properly belongs, leaving general relativity aside for separate consideration as a theory of gravitation.

It must not, however, be thought that we have here a mere piece of reporting or a compilation : the notions of mathematical physics, from geometry to the spinning electron, are synthesised by means of a guiding principle whose proper appreciation is essential to an understanding of the book. This principle appears to be that the concepts and theories of mathematical physics, such as æthers, light, inverse square attractions, curvatures of space, protons, electrons, electromagnetic fields, etc., are somehow more real and fundamental than the observations they serve to correlate and interpret. The former are the constituents of what is variously referred to as " Nature," " the external world," " the actual universe," etc., an entity existing apparently independently of the observer who is engaged in " discovering " its properties, assumed to be rational. Whilst classical physics and even general relativity can be moulded more or less successfully into this philosophical framework, quantum theory, with its electrons that are " really " both particles and waves and also possess spin, proves more awkward. Yet on page 2 Whittaker does define " reality " in a way which would permit him to regard electrons and other unobservables as concepts introduced by the observer for the purpose of interpreting his observations (and so alterable if necessary), when he speaks of " reality " as containing " any factor (of experience) which is the same for all percipients." That he can still maintain his strict realist view is apparently due to a lack of discrimination between *observations* and the *concepts* used to interpret them. For example, all percipients of certain experiments with Wilson cloud-chambers perceive streaks of water-vapour ; but the electrons whose motions are said to " cause " the streaks are not *perceived*, they are mentally constructed in order to interpret the phenomena. Another illustration of this kind of equivalence between observational data and theory is found in the conclusion which Whittaker draws from the impossibility of predicting, by means of the quantum theory, the instant of disintegration of a particular radioactive atom, *viz.* that this prediction is " impossible *not only in present practice but in eternal principle* " (Whittaker's italics). The reason given is that so to modify the theory that prediction would be possible would " entail the renunciation of parts of the existing theory which are soundly based in observation." Now if abandoning a *theory* also meant the renunciation of the *observational data* on which it is based, the argument would have great force. But this is not so, as Part III of this book demonstrates. For it is there shown how a theory as immensely well founded in observation as is the Newtonian theory of gravitation can be renounced in favour of another (Einstein's) simply by re-interpreting all the observational data in terms of a new concept, the curvature of space.

But these are philosophical objections and so will be visible or invisible to each reader according to his temperament. Everyone will be stimulated by reading this book and none can fail to admire the depth of learning to which its pages bear witness. And in these days, when books on mathematics abound in misprints, this reviewer is relieved to record that he noticed only two trivial ones, in the formulæ at the tops of pages 133 and 173 respectively. G. C. McVittie.

ASTRONOMY AND METEOROLOGY

Practical Astronomy. By GEORGE L. HOSMER. Fourth edition revised
and rewritten by JAMES M. ROBBINS. [Pp. xvi + 355, with frontis-
piece and 93 figures.] (New York : John Wiley & Sons, Inc. ;
London : Chapman & Hall, Ltd., 1948. 36s. net.)

THE title of this work is somewhat misleading. A subtitle, " A Textbook
for Engineering Schools and a Manual of Field Methods," gives an adequate
idea of the purpose of the book, which is to provide a text of practical
astronomy for civil engineering students, with no previous astronomical
knowledge, who do not intend to proceed to an advanced study as astronomers.
The theoretical considerations do not, therefore, include refinements beyond
the requirements of work that could be performed with small transits or
theodolites. It is to the authors' credit that these limitations are not only
adhered to in the text but emphasised at all relevant stages.

The early chapters set forth the elements of positional astronomy, with
definitions of various astronomical terms likely to be unfamiliar to engineer-
ing students. In the discussion of the inter-relation of the various systems
of celestial co-ordinates, the problem of introducing spherical trigonometry
is met by merely listing fundamental formulæ in the text to be memorised,
more advanced students finding the derivations relegated to appendices.
Careful attention is paid to the problem of time and its measurement. The
use of ephemerides and the reduction of observations are explained in detail.
Corrections to apply to observed altitudes are discussed, in accordance with
the aim of the text, to a first approximation only. Some 40 pages are
devoted to the description of the astronomical instruments used by engineers,
and such ancillary equipment as chronometers and navigation watches.
The first part of the book ends with a chapter on star identification. This
is, perhaps, the weakest chapter, relying too much upon five hardly adequate
small-scale maps.

The second part of the volume deals with the three fundamental measure-
ments of engineering astronomy—those of latitude, azimuth, and time and
longitude, these two latter being included in one chapter in this new fourth
edition, there being little distinction between their methods of measurement
in practice. The smallest practical details are considered in the step-by-
step descriptions of the observational techniques.

The concluding pages contain useful tables and mathematical appendices.

The text is well proportioned. Admirable features are the inclusion of
worked and unworked examples at the end of each chapter, and the prolific
use of diagrams and half-tone photographs. As is customary with American
books, the photographs are embodied in the text, and not as separate plates,
and they suffer badly in the English edition on a poor-quality paper which
is in sad contrast with the elegant binding.

Adequately fulfilling its prescribed functions, the book deserves the
popularity that has taken it to a fourth edition. It may be recommended,
not only to engineering students for whom it is specifically intended, but
also to those desiring an introduction to positional astronomy from an
astronomical standpoint, provided that they realise that occasional recourse
to more essentially astronomical treatments may be necessary. That it is
not so well known on this side of the Atlantic as in its native environment
may be due, in part, to a parochial tendency to consider problems only as

they arise at latitude 42° N., longitude 73° W. The one minor error which appears to have survived the first three editions may in fact be an example of this tendency; on page 60, "winter" and "summer" should read "northern winter" and "northern summer."

M. W. O.

Climate through the Ages. By C. E. P. BROOKS, I.S.O., D.Sc., F.R.Met.Soc. Second edition. [Pp. 395, with 39 figures.] (London : Ernest Benn, Ltd., 1949. 21s. net.)

CLIMATOLOGY, the long-term aspect of meteorology, is still largely a descriptive science. Such is the complexity of significant theoretical problems that in the study of weather changes we still have to rely largely on empirical or semi-empirical methods. But significant climatic changes are usually slow, so that even empirical studies are difficult unless we can obtain some idea of climatic conditions in the distant past, long before the systematic compilation of accurate weather data. In *Climate through the Ages* Dr. C. E. P. Brooks has set himself the task of collecting together all the more plausible inferences, from a variety of sources, regarding past weather conditions and of welding them together, as far as possible, into a rational self-consistent scheme. The task is a colossal one. The evidence is scrappy and much of it dubious, or at best inconclusive, so that not merely a working knowledge of a wide variety of sciences (meteorology, oceanography, physical geology, palæontology, astronomy, etc.), but also a keen critical sense is needed if the conclusions are to be of value and not simply confusing or misleading. Fortunately Dr. Brooks is well equipped for the task and no one has contributed more to the development of this aspect of climatology. The result is a unique work and if we are not always satisfied with his results or convinced by his arguments we have little right to complain. We cannot, for example, complain of his rather naïve treatment of the relation between temperature and pressure, of the effects of orography, etc., until we have developed a more precise theory to replace it. One might prefer a fuller and more up-to-date account of the general circulation of the atmosphere, a less one-sided treatment of the hypothesis of continental drift (there exist more plausible theories than those of Wegener), and so on. But the fact remains that this is a pioneer work which will serve present and future generations not merely as an excellent guide and work of reference but as a constant source of inspiration.

E. T. EADY.

Oscillations of the Earth's Atmosphere. By M. V. WILKES. Cambridge Monographs on Physics. [Pp. x + 76, with 23 figures.] (Cambridge : at the University Press, 1949. 12s. 6d. net.)

THE oscillations referred to in the title of this attractively written, well-produced monograph are those air-tides or barometric waves induced by the sun and moon by gravitational and, in the case of the sun perhaps, by thermal action ; phenomena which have provided a happy hunting ground for the mathematical physicist since the time of Laplace and which still present a challenge, although the essential problem appears to have been solved in the last decade or so. The peculiar interest of atmospheric tides arises from the fact that, in contrast with the oceans for which the moon provides more than twice as much tide as the sun, the solar semi-

diurnal tide in the atmosphere much outweighs the lunar tide. Kelvin was the first to suggest that this feature might be due to the existence of a natural period of oscillation of the atmosphere so close to twelve solar hours as to provide resonance with the exciting force, but attempts to show that this was indeed the case have only succeeded in the last few years, Taylor, Pekeris and the author having been mainly responsible for the success achieved.

The natural modes of oscillation of the atmosphere depend, as is to be expected, on the distribution of temperature in the atmosphere. Early work on this evaluation was based on simple systems, such as an isothermal atmosphere or one in adiabatic equilibrium, and failed for that reason to provide sufficiently accurate results. We now know that the thermal structure is quite complicated, particularly in the vertical (the subject was recently discussed in SCIENCE PROGRESS, No. 147, p. 488, 1949), and it is to the existence of alternating layers of decreasing and increasing temperature that resonance is due. Herein lies one of the great interests of the study of atmospheric oscillations, for the atmospheric periods are markedly dependent on the temperature distribution at the high levels normally inaccessible to direct observation, the V2 rocket excepted. Thus tidal theory provides a probe as well as an explanation of the observed barometric oscillations. It is found that certain distributions of temperature result in internal reflection aloft of the energy propagated upwards from near the earth's surface by the tide-producing forces. The " mirror " is not perfect and so leakage occurs, giving rise to damped vibrations, the energy being ultimately degraded at very high levels by viscosity and thermal conductivity.

This, and much more, is to be found fully and clearly expounded in the author's monograph : the complex nature of the solar tide which consists of two components—a travelling wave following the sun and a standing wave with pressure alternately high at the poles and the equator ; the beautiful work of Chapman and his collaborators on the amount and variation of the often minute lunar tide and of the exceedingly small but traceable variations in temperature and wind to which it gives rise ; and our knowledge of the tides in the ionosphere and their relation with geomagnetic phenomena. It is a quite entrancing story and the reader, preferably with some mathematical equipment, may expect to enjoy himself largely.

P. A. S.

PHYSICS

Cosmic Radiation. Colston Papers based on a Symposium held at Bristol in Sept. 1948, now published as a Special Supplement to *Research.* Edited by F. C. FRANK and D. R. REXWORTHY. {Pp. viii + 189, with 62 figures.] (London : Butterworth's Scientific Publications, 1949. 25s. net.)

THIS handsomely produced volume marks the opening of a new phase in the substantial support given to research in the University of Bristol by the Colston Research Society. Concluding that benefactions of the kind previously made are less useful now that extensive Government aid to research is at last forthcoming, the Society plans, in collaboration with the University, to hold annual symposia and to publish the " finally considered version " of the papers given as the " Colston Papers," of which this is the first.

It is most appropriate, at a time when contributions of the highest importance in the subject are coming from the Bristol Laboratories, that " Cosmic Radiation " should have been chosen as the topic of the first symposium. The choice, however, of a subject which exhibits an exceptional vigour of development necessarily brings forward the whole question of the form which the permanent record of such a symposium should take. Are the " Colston Papers " to appear for the benefit of a public of wide interests, which will in this way receive annually a report on the present state of knowledge in some particular subject ? Or are they to be directed to the specialised workers of whom those attending the symposia are supposedly representative ? The editorial plan set out in this volume clearly intends the latter, and it is true that a few of the major contributions, and pre-eminently those of leading theoreticians, take the form of general surveys, not accessible elsewhere, of the greatest value to almost all cosmic ray workers, contributions which will in due course provide revealing data on its historical development. The material of experimental research, on the other hand, does not yield so readily to fruitful generalisation and speculation, and it must be observed that the experimental work reported (occupying the greater part of the volume) has almost all been published elsewhere, generally in more critical detail, while some is certainly already obsolete. This situation is, of course, inevitable if the written report is to follow at all closely the lines of the verbal communications made under the restricted conditions which are an invariable feature of modern conferences, and if publication of the whole is to be held up by the slowest revisers, but it does make one wonder whether publication in this form is not altogether out of place.

Substantially unedited collections of conference papers are now frequently published as relatively inexpensive supplements in the format of the regular journals of research. The higher standard of production which has been sought for the " Colston Papers " can most obviously be justified if severe and purposeful editing is imposed by the organisers and accepted by the contributors to subsequent symposia. If the main part of the volume were to consist of a series of invited essay-surveys, it would no doubt be possible to summarise briefly the other communications of the symposium, and some such modification seems essential if the Colston Papers are to have permanent value. J. G. WILSON.

Foundations of Modern Physics. By THOMAS B. BROWN. Second edition. [Pp. xvi + 391, with 181 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 40s. net.)

THE first edition of this book was published in 1940 and was immediately welcomed. The term " Modern Physics " is interpreted as meaning much more than the most recent advances in nuclear research, and Prof. Brown has succeeded well in showing the close relationship which exists between those parts of physics which have changed rapidly during the last generation and the still living older physics from which they have grown. In effect, the book includes those sections of classical physics which a student of about Intermediate or H.S.C. standard will need in order to gain some understanding of modern physics as such, as well as a concise account of more recent work. No mathematics beyond Intermediate standard is used, but this does not mean that the treatment is inexact or superficial. Prof.

Brown is obviously a thoughtful and experienced teacher, and he is careful not to use any over-simplified treatments which may lead to false impressions.

For the second edition the whole text has been revised and a few sections added. The whole outlook of the book is thoroughly up to date. There are remarkably few slips and misprints. At the end of each chapter there are numerical examples and useful bibliographies. The scope of the book is, roughly : electrons and atomic structure, wave theory of light, electrical oscillations and electromagnetic waves, wave properties of particles, spectra, kinetic theory of gases, molecular energy, structure of solids, full radiation and the quantum theory, radioactivity, nuclear physics and cosmic rays.

The book can be commended as a clear and well-balanced introduction to modern physics.

F. A. V.

Physics Tells Why. By OVERTON LUHR. [Pp. x + 387, with numerous figures.] (London : George Allen & Unwin, Ltd., 1949. 16s. net.)

THE only fault that one can find with this book is in its title. Since the time of Galileo, physics has set itself to tell " How," leaving the " Why " to philosophers and theologians. Setting aside this point, we find in the late Dr. Luhr an able instructor in popular physics, one the more qualified in that he spent ten years of research work before an enforced stay in hospital turned his attention to the teaching of physics to those unversed in mathematics.

In this, the second edition, a number of new topics have been added by R. Johnson, who prepared the manuscript of the first edition for the press, on the death of the author, while Ruth Schmidt has added humorous drawings, which are nevertheless very apt. With her aid, Dr. Luhr takes us through the conventional elementary physics course, not forgetting to cite recent applications. It is good to see a chapter on meteorology, which ought to appear more often in an elementary physics course. There is a chapter by the reviser on atomic energy and its possible uses, and another on the non-atomic wartime applications of physics. Finally, there is an examination paper in the magazine style.

Altogether a good present for an enquiring boy or girl, and perhaps a good refresher for his teacher.

E. G. R.

Physics : Principles and Applications. By HENRY MARGENAU, WILLIAM W. WATSON and CAROL G. MONTGOMERY. [Pp. x + 760, with 612 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 44s. 6d. net.)

THIS is a good book which, we are told, has grown out of a collaboration of the authors in a course designed for sophomores who require a thorough and accurate introduction to engineering and the physical sciences. The reviewer was initially too ignorant to name the British equivalents of such students, and an examination of the contents of the book has not enlightened him overmuch. Suffice it to say that the book contains both more and less than is required by Intermediate and Pass Degree candidates, but, let it be added, it would not be an altogether retrogressive step if physics non-specialists were made familiar with the comprehensive material contained in the book rather than with a more detailed knowledge of fewer topics.

The book justifies its title in that lecture demonstrations and apparatus details are omitted, whereas principles are emphasised and topics carefully introduced : thus, for example, a table of values is given to show that intermolecular forces cannot be accounted for by gravitational attraction, a brief outline of the method of mixture *follows* the statement that heat is energy, and the analogy between mechanical and electrical vibrations is made clear by a table of corresponding quantities. Moreover, the methods of the calculus are used more and more intensively as the work proceeds and the reader's knowledge of mathematics is supposed to increase. In outlook and treatment the book is up to date and contains, for example, a note on non-reflecting films and the inevitable reference to the atomic bomb.

The book is so well produced that the statement that 2000 lb. is called a ton will cause no surprise to British readers.

E. J. I.

An Introductory Course in College Physics. By Newton Henry Black. Third edition. [Pp. xvi + 800, with frontispiece, 22 plates and 696 figures.] (New York and London : Macmillan & Co., Ltd., 1948. 37s. 6d. net.)

In the third edition of this book, fundamental principles have been further emphasised at the expense of much technical detail. Certain sections in mechanics, heat and electricity have been expanded and some recent developments in electronics, optics and atomic physics have been omitted. Finally, thought-provoking questions have been inserted at the end of each chapter.

Reading the book for the first time, the reviewer was impressed by the lucid exposition and the relative scarcity of error. Naturally in a book that ranges from a spring balance to the atomic bomb there are sources of criticism, but only a fastidious reviewer would fail to recommend the book. Probably the best recommendation is quite unintentionally in the preface, to wit, that the book was used by many non-specialist teachers to instil the basic principles of physics into U.S. servicemen.

J. W. F.

A University Text-Book of Physics. Vol. II : Sound. By J. H. Poynting and Sir J. J. Thomson. Revised by W. S. Tucker, O.B.E., D.Sc., M.R.I. Tenth edition. [Pp. viii + 251, with 121 figures.] (London : Charles Griffin & Co., Ltd., 1949. 20s. net.)

It must be a difficult task to revise a Physics text-book thirty years old, and one that Dr. Tucker has advisedly undertaken by the process of wholesale scrapping of the original. Although he tells us in the preface that he wishes to pay tribute to the original authors by reprinting certain passages of their material, yet the reader used to the old " P. and T." will find few reminiscences after the first two chapters.

Whatever may have been the original intention of the authors, this series has with the march of time become a text-book for the Pass Student, and this is frankly the person to whom Dr. Tucker addresses himself. The book is, however, more than this. Dr. Tucker has given here an account of the acoustical work of his team in the Air Defence Experimental Establishment of the First World War, which is not to be found published elsewhere and forms an invaluable study for any research worker in atmospheric

acoustics. It was on this work as a basis that radar was developed later. Some might cavil at the inclusion of such matter in a book intended to cover the University Pass Course, but it is already a tradition in this series : and why not ? Poynting in the *Properties of Matter* gave a collected account of his own research into gravitation which is more than the undergraduate needs, but which the reviser has retained, because to throw it out would deprive the scientific world of a model for research. The same may be said of Dr. Tucker's own work.

Altogether a worthy text-book to take its place in the rapidly expanding library of modern acoustics.   E. G. R.

The Structure of Matter. By F. O. RICE and E. TELLER. [Pp. xiv + 361, with 70 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 40s. net.)

THIS book forms the introduction to a series on the structure of matter and contains discussions which should prove useful for the material to be covered in succeeding volumes. As the authors state, " It has been specially designed to show the development of our knowledge of atomic structure and to summarise the results of quantum mechanics." This has been accomplished with a minimum use of mathematics. Schroedinger's equation is missing and the meanings of causality and probability, particles and waves have not been discussed, although there is a brief mention of the uncertainty and correspondence principles. Those conclusions of atomic theory which are often used in quantum chemistry have been briefly considered and the book offers an informal review which, although it may not entirely satisfy the physicist, does provide a summary of familiar topics which should prove useful both to physicists and chemists.

The opening chapters deal briefly with the hydrogen atom, the periodic system, the motion and position of nuclei in molecules, dielectrics and van der Waals' attractive forces. The subject matter in these chapters might have received fuller and more detailed attention. A discussion on the chemical bond is followed by one on forces in the solid state in which the concept of atomic forces is applied to a great variety of structures such as ionic crystals, metals, semi-conductors and insulators. The chapter on magnetic moments is brief and some readers will disagree with the statement that the simplest way of explaining diamagnetism is to consider an atom as a microscopic conductor whose resistance is zero. Molecular vibrations and electronic spectra are described—the material in these chapters ranging from colour and resonance to dissociation energies and the spectra of conductors. The book concludes with an account of nuclear chemistry and the state of matter in stars. Unfortunately, no references are made to the original literature, but the volume is well written, the diagrams are clear and it can be well recommended to all who are interested in a qualitative account of the structure of matter.

F. H. NEWMAN.

Practical Spectroscopy. By C. CANDLER, M.A., F.Inst.P. [Pp. viii + 190, with 4 plates and 113 figures.] (London : Hilger & Watts, Ltd., Hilger Division, 1949. 21s. net.)

THIS book might be conveniently and correctly described as a practical manual for users of the Hilger wavelength spectrometer, but only those who

are aware how manifold are its uses would realise the full implications of such a description. There are, in fact, few procedures in experimental spectroscopy which are not covered, and there is no other book known to the writer which brings together so much valuable data and information pertaining to this field. It will be of the greatest assistance to any student of physics, chemistry or biology who undertakes spectroscopic measurements, whether they be made with the wavelength spectrometer or not. As respective examples of the kind of experiment described, we might instance the determination of wavelengths by the Fabry-Perot interferometer, absorption spectrophotometry and the estimation of trace elements in plants. The experiments described vary in standard from those commonly performed in undergraduate courses (e.g. Edser-Butler fringes) to those of post-graduate type (e.g. estimation of copper with dithizone). Nor are they confined to straightforward visual and photographic methods, but include investigations of infra-red and Raman spectra. It is perhaps doubtful whether the short chapter on the structure of line spectra was worth including, in view of the impossibility of any adequate treatment of this subject in such a small compass, but even here the author has managed to include some matter of practical value which is not readily available elsewhere.

The book is liberally illustrated with diagrams of all kinds, and there are four excellent plates reproducing spectrum photographs of various types. There is a useful bibliography and subject and author indices. Recent developments, such as the application of photomultipliers to spectroscopy, are only briefly mentioned, but this is doubtless due to unavoidable delays in publication. The production is of high quality, and no errors or misprints have been detected.

Even the experienced spectroscopist will find much of value in the book, but it will be indispensable to every apprentice to the profession.

W. E. C.

Absorption Spectrophotometry. By G. F. LOTHIAN, M.A., F.Inst.P. [Pp. 196, with 71 figures, including 6 plates.] (London : Hilger & Watts, Ltd., 1949. 26s. net.)

The Practice of Absorption Spectrophotometry (second edition, 1934) by F. Twyman and C. B. Allsopp has been completely revised and re-written by Mr. Lothian, making a new book.

The principles of spectrophotometry are explained clearly and the treatment of methods of calculation in the application of spectrophotometry to analysis is admirable.

The second part of the book on applications consists of well-chosen examples of theoretical problems and their background, together with some neat solutions of practical problems using ultra-violet or infra-red absorption.

The third part of the book deals with techniques of visual and photographic and photoelectric spectrophotometry, with infra-red methods and with light sources, cells and solvents. A great deal of useful information has been packed into this section.

The outstanding developments since 1939 are in the field of infra-red spectroscopy—to quote Lothian : " Before the nineteen-thirties it was generally necessary to spend a whole night painfully plotting, perhaps one spectrum. Then automatic recording became fairly general, and the time required for plotting a spectrum was reduced to 15 or 30 minutes, and now

the use of cathode ray tubes has reduced the time to about a minute, for a similar spectrum range."

Mere speed of working would not account for the progress which has been made. It has been a result of improvements in design going hand in hand with acumen in the use of the instruments.

The book provides an excellent general survey, but parts of it could with advantage be expanded in later editions.

R. A. M.

Electricity and Magnetism. By C. L. REYNOLDS, M.A. Second edition. [Pp. x + 366, with 291 figures.] (London : G. Bell & Sons, Ltd., 1949. 7s. 6d. ; Part I separately, 5s.)

SINCE its first appearance in 1926 Mr. Reynolds's text-book has been reprinted sixteen times and has evidently met with wide approval and served the purposes of many physics teachers preparing candidates for examinations at the S.C. and H.S.C. stages. Recent advances in physics and the concomitant changes in the syllabuses of the examining bodies have made necessary a revision of many of the standard text-books, not all of which have survived the process of "rejuvenation." Whether the present book has been sufficiently revitalised to cope with the competition of the several lusty newcomers in this field remains to be seen, and will in large measure depend on how much of the modern material the physics master expects to find in a modern formal text-book of electricity.

The author admits in his preface to the difficulty in making selections from the mass of new material available, and his final solution is a compromise to avoid "making the book unwieldy." Thus, although there is an adequate introduction to electronics, and a useful chapter on radio-communication, theories of atomic structure receive scant attention. Bohr's atom merely gets honourable mention, and the structure of the nucleus and nuclear transformations have only a passing reference. These are serious omissions from a modern text-book of electricity, and the present book might well have been extended a further 40–50 pages to include these and other topics, as well as to amplify more of the earlier work (particularly the section on the potentiometer), and to give fuller theory in parts and generally more experimental detail. Many of the diagrams seem to have suffered from over-reduction, and the general impression is one of austerity.

Nonetheless there is much of value in this book, the chapter on alternating currents (which has been considerably extended), and the one on the behaviour of motors and dynamos being particularly good, and physics masters should certainly inspect a copy.

F. TYLER.

Theory of Atomic Nucleus and Nuclear Energy-Sources. By G. GAMOW and C. L. CRITCHFIELD. Third edition of *Structure of Atomic Nucleus and Nuclear Transformations.* International Series of Monographs on Physics. [Pp. viii + 344, with 5 plates and 62 figures.] (Oxford : at the Clarendon Press, 1949. 30s. net.)

THE lack of adequate text-books published in England on nuclear physics is well known, and the latest revision of Prof. Gamow's book, now published in collaboration with C. L. Critchfield, is therefore particularly welcome. The history of the two earlier editions, both of which reached publication

at a moment when fundamental advances rendered large parts obsolete, might well have daunted the authors, but the stability inherent in the very scope and detail of experimental material now available makes one confident that this volume will not suffer the fate of its predecessors.

The general plan of the book, leading inductively from the elementary properties of nuclei to nuclear forces, general theory of nuclear structure, the β-transformations, spontaneous disintegration, collision transformations, thermonuclear reactions and chain reactions, is undoubtedly satisfying, although it makes considerable demands on initial knowledge : when this has been assumed the greater part of the treatment is of conspicuous clarity. The first chapter might with advantage have been expanded, since the reader is unlikely to have memorised much of the experimental material involved and since the tabulated data is not immediately assimilable. The first plate, also, which refers to this chapter, cannot be regarded as satisfactory, for the reader is left quite uncertain on what mental plane he is to accept the rugged plasticine pinnacles depicted there.

The chapter on spontaneous disintegration is the only point at which anything of the first edition remains. Now, however, a general considera-tion of the energetic limitations of nuclear division serves as an introduction both to fission and to α-activity. The change of emphasis in this chapter illustrates excellently the development of our understanding of nuclear problems in the intervening years.

Most readers will probably go out of turn to the fascinating chapter on thermonuclear reactions in astrophysics, a subject to which both authors have made important contributions. The excuse put forward in the preface, that this chapter covers ground not yet adequately treated in texts on astrophysics, is certainly not needed, and it would be most unfortunate had any contingency led to its exclusion. The various sections, both established and speculative, provide an exceptionally satisfactory ground-work to topics of absorbing interest.

The excellent standard of production is fully up to that expected from the Clarendon Press.

J. G. WILSON.

The Atomic Age. Sir Halley Stewart Memorial Lectures for 1948. [Pp. 149.] (London : George Allen & Unwin, Ltd., 1949. 7s. 6d. net.)

THE Halley Lectures make a most welcome reappearance after a lapse of ten years. The Sir Halley Stewart Trust, founded in 1924, aims at providing means for research towards the Christian Ideal in Social Life, and the first memorial lecture sponsored by the Trust which appeared in 1927 was the precursor of a distinguished group.

The 1948 lectures represent the contributions of an eminent group of specialists to the social and international problems brought about by the release of atomic energy. They include : " The Scientific Achievement," by M. L. E. Oliphant ; " The Military Consequences of Atomic Energy," by P. M. S. Blackett ; " The Economic Repercussions of Atomic Energy," by R. F. Harrod ; " Values in the Atomic Age," by Bertrand Russell ; " The Political Repercussions of Atomic Power," by Lionel Curtis ; and " America as Atlas," by D. W. Brogan.

The essential method of production of atomic bombs and the impact

of this new weapon on modern civilisation are discussed in clear and simple language. The authors will need no special introduction to many, but the production would have been improved by the inclusion of a brief record of its illustrious group of contributors.

The Halley Trust are to be congratulated on this venture, for surely the release of atomic energy is the most significant event of our age and the misuse of the new power placed in the hands of mankind must be uppermost in the mind of every thoughtful citizen. There is no escape from our international responsibility in this and the subject of these lectures is therefore of the highest importance to us all. The contributions of these eminent scholars should be in the hands of all who would not try to evade the realities of the age in which we live.

<div align="right">G. E. HARRISON.</div>

Fundamentals of Discharge Tube Circuits. By V. J. FRANCIS, B.Sc., A.R.C.S., F.Inst.P., M.I.E.E. Methuen's Monographs on Physical Subjects. [Pp. x + 134, with 40 figures.] (London : Methuen & Co., Ltd., 1949. 6s. 6d. net.)

UNTIL the appearance of this book by a member of the G.E.C. Research Laboratories there was very little systematic information available about the electrical circuit properties of the gas discharge tubes now increasingly used for illumination. The author has here met the need for a full survey in a most competent manner. Throughout the text the emphasis is on fundamental principles of the electrical behaviour of discharge tubes in their associated circuits. In contrast with many available descriptions of circuits in common use, this monograph describes the principles on which circuit design must be based.

The scope of the book is well indicated by the chapter subjects, which are (1) Discharge tubes as circuit elements, (2) D.C. operation, (3) Dynamic characteristics, (4) Waveforms on A.C., (5) A.C. operation, (6) Initiation of the discharge, and (7) Typical circuits, and design principles. The treatment includes all discharge devices whose characteristics depend on the positive column behaviour (thus including all the tubes widely used for illumination purposes) : it excludes those in which cathode phenomena are paramount and those operating at very low pressures and current densities.

Clear and careful presentation makes the book doubly valuable.

<div align="right">H. MARRIOTT.</div>

Radio Wave Propagation. [Pp. xii + 548, with 601 figures.] (New York : Academic Press, Inc. ; London : H. K. Lewis & Co., Ltd., 1949. 90s. net.)

THIS book provides a " consolidated summary technical report of the Committee on Propagation of the National Defense Research Committee " of which C. R. Burrows was Chairman. The editor of the book is S. S. Attwood. The title is misleading, since the book deals only with that very specialised field of radio-wave propagation in which the frequency is greater than 30 Mc./s. ; moreover, the very large part of the book is devoted to frequencies of 1000 Mc./s. and above and the emphasis is predominantly on radar applications. Once this restriction is realised, however, the reader will find this a valuable and stimulating book.

It has been produced by the skilful combination of a series of technical

reports presented to the Committee during the war by workers in several parts of the world. This method of production has led, inevitably, to some repetition and to some variation of standard and of verbosity. The work is divided into three " volumes " all bound together in one book.

The reader new to the subject should first study Vol. III which presents, in text-book form, a full survey of the " Propagation of radio waves through the standard atmosphere," *i.e.* an atmosphere in which the temperature and water vapour content vary upwards in a specified way. The treatment is intended for those with " college training in radio, physics, or electrical engineering " and, starting with fundamental concepts, leads up to ideas of gain, receiver sensitivity, scattering cross-section (of radar targets), antennas (in unexpected detail), refraction in the troposphere, and reflection from the surface of the earth. A long chapter deals in detail with the calculation of radio gain and coverage diagrams and includes a series of worked examples for typical special cases. Diffraction by terrestrial obstacles is next dealt with and then follows a chapter on the siting of radar stations.

Those with some previous knowledge of the subject will be more interested in Vol. I, " Technical Survey " and Vol. II, " Radio Wave Propagation Experiments." Part 1 of Vol. I gives an account of the theory of " non-standard propagation " such as occurs when the troposphere departs from the simple standard form. This account completes the " text-book " account of Vol. III which is restricted to the case of the " standard atmosphere." Part II includes a series of specialist reports, the longest and most interesting of which deals with the siting and coverage of ground radars and, amongst other things, with diffraction by terrestrial objects and diffuse reflection from the land. Vol. II describes experiments on the appropriate aspects of meteorology and on the measurement of reflection coefficients of ground and sea, experiments on dielectric constants, absorption and scattering, storm detection, the nature of echoes from radar targets, and measurements of angle of arrival of waves.

The appendix includes a most valuable classified bibliography of reports, most of which were produced during the war and have never been officially " published."

The book provides a most valuable text-book on the subject of tropospheric radio propagation, and can be recommended both to those with little knowledge of the subject, and to the expert.

J. A. RATCLIFFE.

Waveforms. Edited by BRITTON CHANCE, FREDERICK C. WILLIAMS, VERNON HUGHES, EDWARD F. MACNICHOL, and DAVID SAYRE. [Pp. xxii + 774, with 758 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 85s. net.)

THIS book forms Vol. 19 of the Radiation Laboratory (M.I.T.) series on radar techniques. The field covered by the work is defined by the following quotation from the introduction. " This book deals with the applications of circuit techniques to the generation of waveforms, both sinusoidal and otherwise, and to the manipulation of waveforms to meet specific needs. The title *Waveforms* refers to currents or voltages considered as functions of time in a rectangular coordinate system." The book is, in fact, the main work in the series dealing with the *basic circuit techniques of radar*. Other volumes in the same series cover applications of the basic techniques, *viz.*

Vol. 5 (*Pulse Generators*), Vol. 20 (*Electronic Time Measurements*), and Vol. 22 (*Cathode Ray Tube Displays*).

This book maintains the consistently high standard of the series. It is pleasing to see that both American and British work is included. In spite of co-operation between radar establishments during the war, there remained considerable differences in approach to circuit problems on the two sides of the Atlantic. In its most obvious form this showed itself in the extensive use by the American workers of the double-triode type valve, in contrast with the British preference for the high slope pentode. Here we find circuits using both British and American valve types described and compared. The short Glossary could, however, be usefully expanded to include a few more terms which differ in British and American usage.

The circuits described are classified according to function rather than according to type. Thus a basic circuit type such as the multivibrator appears under several different headings according to its various possible uses. This procedure is certainly justified in what is essentially a reference work. It means that a circuit designer with a problem to solve can quickly compare the various circuits which may satisfy his requirements, and can be sure that he has not overlooked any of the possibilities.

There are particularly valuable chapters on mathematical computations performed by means of waveforms, which include much original material. The book can be recommended without qualification as an outstanding contribution to the literature on this subject.

B. H. BRIGGS.

Electronic Time Measurements. Edited by BRITTON CHANCE, ROBERT HULSIZER, EDWARD MACNICHOL and F. C. WILLIAMS. M.I.T. Radiation Laboratory Series. [Pp. xviii + 538, with 383 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 59s. 6d. net.)

To quote the Preface : " The object of this book is to present the method of approach to the problems of time and distance measurement, by manual and automatic means, and the practical circuits employed for these purposes." The book is essentially concerned with the control, timing and visual presentation sides of radar systems. A good deal of the included material is of British origin, a fact which it gives pleasure to see generously acknowledged.

The subject has not been dealt with so much from the point of view of theoretical principles, as from detailed descriptions of existing systems, illustrated by their circuit diagrams with the full numerical values marked in, which, it might be argued, is not helpful to the designer of future systems. Indeed, it is perhaps true to say that this whole subject has not yet been developed far enough for the various circuit principles, and their interrelationships, to be presented on a theoretical basis. The urgency of radar development during the war was such as to hamper the systematising of theories of design and the development of a condensing mathematics comparable, for example, to linear network analysis. This has been recognised in the introductory remarks to Chap. 9 ; the editors have, however, tackled this obstacle in an excellent way, partly by developing the material in the book in a very logical manner, and partly by the generous use of block diagrams. These diagrams, and the schematic circuits, show clearly the functions of the various component parts of a system and the interplay

between them, thereby greatly assisting towards comparative study of systems. This volume should perhaps be regarded as a companion to Vol. 19 (*Waveforms*), since this latter contains details of circuit behaviour which have been necessarily omitted here.

A useful Glossary is included, defining some (but by no means all) of the jargon which has grown up around this subject ; a helpful inclusion, since the etymology of some of the terms is vague ! The book is extremely comprehensive and will be of use not only to radar designers, but all concerned with electronic computing, control and pulse communication systems.

Colin Cherry.

Metal Rectifiers. By H. K. Henisch. Monographs of the Physics and Chemistry of Materials. [Pp. xii + 156, with 55 figures.] (Oxford : at the Clarendon Press, 1949. 15s. net.)

The writer on this subject must often find himself in the tangled country which divides idealised physical theory from the complex and baffling behaviour of actual materials, and much depends on how he sets about finding a path through the jungle. His book could so easily degenerate into a scrap-book of curious observations and snippets of theory. Dr. Henisch has avoided this pitfall by centring his book round his excellent fifth chapter on " Modern Theories of Rectification "—a chapter occupying a third of the book. While it is true that most of the material in this chapter is already available elsewhere, and that the treatment is at times necessarily brief and in summarised form only, it is a well-written account, both of rectifier theory and much of the relevant theory of solids, in a connected form very difficult to come by elsewhere. Detached from Chapter V, but clearly part of the same story, Chapter VI gives a brief account of earlier theories of rectification. As a sort of technical introduction to these two chapters, which form the core of the book, the first four chapters describe certain aspects of manufacture, the characteristic properties of the manufactured article, and measurements on rectifiers. This part of the subject is so complex that much credit is due to the author for judicious selection. It is probably the great difficulty of selection and necessary compression, however, which has made this section rather less satisfactory than the main chapters. It is certain that the requirements of brevity have imposed severe limits on the author here, and are no doubt responsible for some obscurities. Some of the summarised explanations are not at all easy to follow. It is to be hoped that, when the exigencies of cost and space become less cramping, this section of the book may be expanded. The final Chapters, " Notes on Rectifier Operation " and " Notes on Rectifier Development," contain, in very brief and somewhat detached form, a good deal of technical information and suggestions likely to be of value to the user of rectifiers.

The book concludes, and special attention ought to be drawn to this, with a very full bibliography on semiconductors and rectifiers.

So much of this book is excellent and accurate that small criticisms ought not to be taken too seriously—personal prejudice in the reader must be allowed for. One or two such criticisms will occur to most readers, however. It seems a pity, for instance, to use the term " thermal diffusion," which has an accepted and different connotation in the kinetic theory of gases, for what appears to be just " diffusion " (pp. 86, 102). Most people would disagree, also, with the units of thermal conductivity given on p. 10.

Smaller blemishes like these apart, however, the book is a valuable addition to the literature of rectification, and a worthy member of the Oxford series of monographs.

<div align="right">J. P. A.</div>

Laboratory and Workshop Notes. Edited by RUTH LANG, Ph.D., A.Inst.P. [Pp. xii + 272, with 195 figures.] (London : Edward Arnold & Co., 1949. 21s. net.)

ALL physicists and others will be familiar with the laboratory and workshop notes which have formed a characteristic feature during the past twenty-five years of the *Journal of Scientific Instruments*. These notes represent a fund of practical knowledge, based on experience, but, generally speaking, are not available to many who would welcome such helpful hints. The Board of the Institute of Physics believes, quite rightly, that these simple and useful devices should be more widely known in laboratories and workshops. Accordingly Dr. Ruth Lang has made a selection of these notes, on the basis of general usefulness, and the present book is the result. The number of such articles reproduced is 181, which represents less than half of those appearing in the journal over the period mentioned. It could not have been an easy matter to decide which articles should be included, but the author has made a good choice.

The book is divided into eight arbitrary sections, the first of which includes laboratory tools, processes and devices such as hole-drilling, gears and a comprehensive article on cements and waxes. This is followed by a section on clamps, apparatus and agitators, and one on soldering, brazing and welding, which includes advice on the welding of fine wires and an informative article by Boys on the whole subject. The section on the technique of glass manipulation, silvering, vacuum technique and devices includes a description—also by Boys—of the manipulation of glass which embodies all his own ideas and practice and which should be read—even in these days—by all glass workers. Various seals, traps, vacuum leaks, valves—important features in high vacuum technique—receive full treatment. The remaining sections are composed of articles on electrical, magnetic and optical devices and the flow of liquids. So diverse is the nature of the contents that it is impossible to mention more than a few of the more important ones.

The diagrams are numerous and good, and there is an adequate index. The book can be recommended to all workers in laboratories and workshops, and it is hoped that the promised further volume will soon appear.

<div align="right">F. H. NEWMAN.</div>

Components Handbook. Edited by J. F. BLACKBURN. M.I.T. Radiation Laboratory Series, Vol. 17. [Pp. xviii + 626, with 368 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 68s. net.)

To the radio research or development engineer, the cataloguing and testing of components and the drawing up of specifications is usually a dull, if necessary, job. It is regrettable, therefore, that the *Components Handbook* should devote so much space to these topics, while excluding information of a more general nature which would be more universally useful. The majority of the book gives the impression that the authors have paid more

attention to the wartime Joint Army-Navy component specifications than to the presentation of more fundamental principles of component design.

The chapters on " Iron-cored Inductors " and " Electromagnetic Delay Lines " are, however, well written, presenting useful design data in a convenient form. Chaps. 2 and 3, which deal with fixed resistors, include some valuable information about the H.F. characteristics of composition resistors, and a good summary of the properties of varistors. Other chapters which may be useful, though their appeal is rather specialised, are " Piezoelectric Devices," " Supersonic Delay Lines " and " Rotary Inductors."

The remaining seven chapters appear, however, to be little more than catalogues of components developed at, or for, M.I.T. during the war years. This is particularly so of Chap. 13, " Relays and Related Devices," which concludes with five pages of tabulated information on no less than 120 different types of relay. Well may the British engineer be thankful for the efforts of the G.P.O. which have reduced the number of basic types of relay to three !

On the whole, the reviewer feels that, while the *Components Handbook* would no doubt have been useful in the United States in 1947, the British engineer at the present time is not likely to find it of great value.

<div style="text-align:right">K. E. MACHIN.</div>

Principles of Servomechanisms. By GORDON S. BROWN and DONALD P. CAMPBELL. [Pp. xiv + 400, with 207 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1948. 40s. net.)

THIS book is a treatise on the theory of automatic control systems of the closed-loop type, in which the error between the desired state of the controlled element and the existing state is measured and the mechanism seeks continuously to bring the error to zero. The book is not a catalogue of particular mechanisms or arrangements ; its authors seek to set out the theoretical treatment of the dynamics of servomechanics by the methods of transient response and sinusoidal response.

Problems of two types may face the designer of automatic control systems. He may wish to analyse the performances of an existing mechanism or he may wish to determine the characteristics required in the components of a mechanism in order that it shall fulfil given performance requirements. While the former problem is given adequate treatment, the latter, that of the synthesis of systems, is the central theme of this book, and it is for this reason particularly that the volume is a welcome addition to the literature on the subject.

The work begins with the formulation of the problem of the closed-loop system in terms of differential equations. The treatment is then extended to the use of the Laplace transform, and to the representation of a system by a transfer function ; the use of the transfer function as a means in the synthesis of systems is demonstrated. The book ends with an explanation of approximate methods by which the transient behaviour of a system may be determined from its frequency function. The treatment is confined throughout to linear parameters. There is no analysis of the energy aspects of servomechanisms, but such matters will present little difficulty to those who have mastered the book. A number of problems on the work of each chapter is included in an appendix, and a useful bibliography is also provided.

Although there are occasional lapses in which the writing becomes obscure, the presentation is, in the main, good, and the treatment reasonably complete. The book can be recommended both to the student and to the engineer, who will find in it much which will aid practical design.

A. A. H.

Worked Examples in Electrical Engineering. By W. T. PRATT, B.Sc. (Eng.), A.C.G.I., D.I.C., A.M.I.E.E. [Pp. 263, with 134 figures.] (London : Hutchinson's Scientific and Technical Publications, 1949. 25s. net.)

THIS collection of nearly 200 numerical examples is similar in character to the compiler's previous book of *Examples in Electrotechnology*, to which it forms a sequel. It is intended for students preparing for the higher National Certificate, the City and Guilds Final Certificate, Part B of the I.E.E. Examination, and some subjects of Final Degree Examinations. The questions are largely extracted from previous examination papers, and in most cases the solution is confined to the numerical part of the question.

Classification of the examples is by subject matter. Six of the 15 chapters deal with A.C. machines, one with mercury arc rectifiers, one with D.C. machines, and one with A.C. circuits. In the second section there are three chapters on the transmission of energy by cables and lines, two on the economics and technics of generation, and one on fault and protection calculations. There are also useful definitions of the terms and symbols used, a bibliography and an index. Electronics and measurements have been purposely excluded from the book.

Very clear working of the solutions, with adequate explanation of the principles involved, will make the book extremely useful to students preparing for examinations.

H. MARRIOTT.

CHEMISTRY

A Class Book of Physical Chemistry. By T. MARTIN LOWRY, C.B.E., M.A., D.Sc., F.R.S., and SAMUEL SUGDEN, D.Sc., A.R.C.Sc., F.R.S. Second edition. [Pp. x + 454, with 75 figures and 101 tables.] (London : Macmillan & Co., Ltd., 1949. 8s. 6d. net.)

EVER since the publication of the first edition in 1929, Lowry and Sugden has been well known and esteemed as giving a simple and attractive introduction to physical chemistry. In preparing this new edition, Prof. Sugden has, it would appear, chosen wisely in resisting the temptation of introducing a large number of the more recently developed aspects of the subject, which could have had, at the most, only scant reference in a book of this size and purpose. He has therefore confined himself to alterations or additions to those sections which would have left an incorrect impression without them. Of these the principal seems to be a section dealing with activities and activity coefficients, written in a most simple and attractive manner. It does seem a great pity, however, that such introductions have necessitated a rather clumsy pagination.

Fashions in the approach to physical chemistry may change, but for those who still prefer a simple and essentially practical route, calculated to whet the interest of the student, they will still find it here. The examples chosen may be all classics, and some of the branches of the subject which have now

fallen into the background may be given what now appears rather too large a proportion of the available space, but it is an excellent preliminary to a more profound study. In this direction it is pleasing to note that the symbolism has been revised to accord with modern practice.

J. W. SMITH.

Acids, Bases and Non-Aqueous Systems. By LUDWIG F. AUDRIETH. Twenty-third Annual Priestley Lectures. [Pp. viii + 66.] (Pennsylvania : Phi Lambda Upsilon, Dept. of Chemistry, State College, 1949. $2.00.)

IN this small volume the author summarises the historical development of the acid-base concept and then proceeds (Chaps. II and III) to discuss the Lowry-Brönsted and Lewis theories with particular reference to the analogies between ammonia derivatives and oxygen-containing compounds. Chap. IV includes a classification of nitrogen derivatives based upon nitrogen hydrides (called hydronitrogens), which in many cases are unknown in the free state, and the analogy between these compounds and those of oxygen. The concluding chapter is devoted to the applications of these theories to reactions occurring in fused melts.

In accord with its character as a reprint of a lecture course, the book is written in an attractive popular style. Although the contents of the first half may be regarded as classical, there is much to stimulate the interest and imagination in the last two chapters, which are based principally on the author's own work. Some of the suggestions put forward may not receive general acceptance but the approach is very interesting, especially in the development of nitrogen chemistry as a field intermediate between inorganic and organic chemistry. One shudders, however, at the suggestion (p. 56) that " Perhaps it is time for the nitrogen chemist to divorce himself from both of these two accepted fields and to label himself specifically a ' nitrogen chemist.' "

J. W. SMITH.

The Theory of Solutions of High Polymers. By A. R. MILLER. [Pp. viii + 118, with 12 figures.] (Oxford : at the Clarendon Press, 1948. 12s. 6d. net.)

THE behaviour of solutions has been one of the prime interests of physical chemists. Since the formulation of Raoult's Law connecting vapour pressure and composition, the general problem has been to account for the deviations in terms of the nature of the mixed molecules. Although considerable progress has been made, the complete solution is far from sight.

All this work has been concerned with mixtures of molecules of roughly the same size and shape. It might, therefore, seem to be completely hopeless to attempt to deal with a mixture of big molecules (high polymers) and small molecules, for the deviation from Raoult's Law, even at concentrations as low as 0·1 per cent. by weight, can be very serious—so serious in fact that a new kind of theory is needed to deal with the phenomena. The aim of the theory is to get a first approximation to a relationship between vapour pressure of the solution and composition. This is the theme of Dr. Miller's book and the approach is by means of statistical mechanics. Hence the problem is to set up a model, and this is the controversial part, in which the segments of a linear polymer occupy a number of points in a lattice, which represents

the solvent. Such a model is then treated by the standardised methods of statistical mechanics in order to find the manner in which solute and solvent can be arranged. Dr. Miller shows that this approach is successful in accounting for the behaviour of one or two systems which have been investigated over a sufficient range of concentrations.

The emphasis is, of course, on the theoretical side, and the book is not easy reading for the chemist, though a brief introduction to statistical mechanics makes it unnecessary to go to the larger standard texts for the preliminary mathematical devices needed for this kind of treatment.

It is to be hoped that the publication of a book of this kind will, on the one hand, show the difficulty of getting an acceptable model, having regard to the assumptions made, and also stimulate the experimental scientist to explore, over a wider range of concentrations than hitherto, the behaviour of high polymer solutions.

H. W. MELVILLE.

Surface Tension and the Spreading of Liquids. By R. S. BURDON, D.Sc., F.Inst.P. Second edition. Cambridge Monographs on Physics. [Pp. xiv + 92, with 22 figures, including 3 plates.] (Cambridge : at the University Press, 1949. 12s. 6d. net.)

THIS edition extends the first, by referring to some recent work. The most valuable chapters are those on mercury surfaces and the spreading of liquids on mercury, which includes the author's own work. The rest of the book consists of short, but clear, notes on very many points on Surface Chemistry. The book is perhaps not systematic enough to give a beginner a balanced idea of the subject, and a person already acquainted with the principles will find much of it very elementary ; but it may draw attention to papers not sufficiently noticed in other books. There are a few inaccuracies : e.g. liquid expanded films are called " gaseous " on p. 59. Without pretending to give a full account of the subject, the booklet has distinct value.

N. K. A.

Surface Chemistry : Papers presented for a Discussion of the Société de Chimie Physique and the Faraday Society, October 1947. [Pp. viii + 334, with 13 plates and numerous figures.] (London : Butterworth's Scientific Publications, 1949. 25s. net.)

THIS collection of over 40 papers describes recent work in many branches of Surface Chemistry. The veteran, and still most ingenious Henri Devaux, in whose honour the meeting was held, opens with an account of the expansion of films of simple substances on mercury, owing to absorption of water from the air. Guggenheim summarises, with masterly conciseness, the fundamental theorems of surface thermodynamics. There are interesting contributions on the equilibrium between, and changes in, surface phases ; on monolayers of aliphatic substances and of proteins, at areas from closely packed up to many thousand sq. Å. per molecule, and their penetration by soluble amines ; the distribution of ions in the neighbourhood of monolayers and of ionic micelles ; complexes between proteins and paraffin chain salts in aqueous solution ; and on the separation of hæmoglobin and catalase by frothing. A good many of these papers, as is inevitable in a discussion, deal with work already published, but are none the less valuable in proximity

to the others. Some of the later papers, from the Cambridge Laboratory of Colloid Science, attempt a correlation between the proportics of surface films and biological action, including bactericidal power ; and a study of the amount of paraffin chain salts taken up by bacteria and suspensions of various insoluble organic substances ; also the electrokinetic potential is described.

The volume will be indispensable to serious students of Surface Chemistry, and of Physical Chemistry applied to Biology.

N. K. A.

Surface Active Agents. By A. M. Schwartz and J. W. Perry. [Pp. xii + 579, with 51 figures.] (New York and London : Interscience Publishers, Inc., 1949. 80s. net.)

A comprehensive book on this topic has long been needed, not only by those concerned with the technological uses of surface active agents (soaps, wetting agents, detergents, etc.), but also by those interested in more fundamental studies.

The aims of the present volume are given by the authors as follows :

" This book is an attempt to summarize the achievements of the last three decades in developing a host of new surface active agents. The different types of products are reviewed with particular attention to their laboratory synthesis, commercial production, and characteristic properties. Special attention has been directed to the numerous practical applications of surface active agents and to their utilitarian effects— foaming, wetting, detergency, emulsification, spreading, etc. In order to provide background for a better understanding of the diverse practical applications and related effects, the fundamentals of the chemistry and physics of surface phenomena have been summarized separately. It was our aim to present a well-integrated picture of the present state of development of surface active agents. It is hoped that this book may prove interesting and helpful to practising chemists in general, to advanced students in chemistry and chemical technology, and particularly to specialists in the production, investigation, and application of surface active agents."

The book is accordingly divided into three sections : Part I, Processes for synthesizing and manufacturing surface active agents ; Part II, The physical chemistry of surface active agents in theory and practice ; Part III, Practical applications of surface active agents.

Considering the magnitude of the task, the authors are to be congratulated on their achievement. It is unfortunate that since the book was written certain aspects of the physical chemistry of surface active agents have been cleared up, since an understanding of many of the practical uses depends upon the physico-chemical factors involved. For example, it is now generally agreed that the properties of concentrated soap solutions, including the X-ray data, are adequately explicable on the basis of a single micellar structure, the spherical, Hartley, type.

The literature, both patent and scientific, has been very well covered, and the authors have not fallen into the all-too-common habit of only recognising work carried out in their own country.

The reviewer's only major criticism concerns the price, which will greatly restrict the book's availability to people in this country.

A. E. Alexander.

Crystals and X-Rays. By KATHLEEN LONSDALE, D.Sc., F.R.S. [Pp. viii + 199, with 13 plates and 138 figures.] (London : G. Bell & Sons, Ltd., 1948. 21s. net.)

X-RAY crystallography, the chief tool of structure-analysis, is curiously amorphous. Its creators had to formulate their own background, largely physical. But its primary disciplines are so broad, and the subjects it now serves so varied, that specific training is unstandardised and there is still room for an authoritative conspectus sketching the scope of X-ray methods and acting as guide and source-book.

In seven compact chapters this little volume, based on a course of public lectures, does so admirably. Historical development, generation and properties of X-rays, crystal geometry and symmetry, and determination of geometric structure and atomic and electronic distributions make solid reading. Chapter VI on extra-structural properties and " real crystals " is the highlight : the importance of extinctions is clearly stated and elegantly illustrated, while the section on thermal effects is peculiarly the author's own. Practically the whole of the structure-analytical field is covered in the crowded topics of the final chapter, which ranges from the fine detail of bonding, through the order-disorder of alloys and mixed crystals, to random and defect structures and the broad biological field of fibres and proteins. Guidance is perhaps less sure on purely chemical aspects, and the early debt of X-rays to chemistry is not unduly stressed.

Treatment throughout is revealing : thorough, concrete, factual, all-embracing : descriptive without room for proofs, but neglecting no difficulties : the wealth of illustrations admirably selected and of international flavour : analogies homely and pointed : truly in the Bragg tradition. While modern technique and results are finely exemplified, the stress is on principles and types with avoidance of unthinking routine machinery.

The modest claims of the preface are fully met. What gives these pages their wider appeal is that they are the product of intense experience of one who was from the first of the elect, and whose supreme mastery of the physics of her subject is paralleled only by the magnitude and variety of her contributions to its growth and organisation. The book will be read with profit not only by those industrial administrative and technical staffs to whom it is primarily addressed, but by most practising crystallographers. It will revolve memories in those privileged workers who experienced the author's generous, sympathetic and clear guidance at the right hand of W. H. Bragg, the nucleus of that cybotactic centre, the Davy-Faraday Laboratory of the Royal Institution, in one of its happiest periods of light and leading.

I. MACARTHUR.

Preparation and Characteristics of Solid Luminescent Materials. Edited by GORTON R. FONDA and FREDERICK SEITZ. [Pp. xvi + 459, with numerous figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1948. 40s. net.)

THE International Conference on Solid Luminescent Materials held at Cornell in October 1946 was a specialists' meeting which inevitably demonstrated many of the weaknesses of specialised research. This account of the symposium consists of the text of the 29 papers read and some of the discussion. On the whole the conference compares somewhat unfavourably with that

of the Faraday Society in 1938, in the main owing to concentration during the war on technical problems such as the application of luminescent materials to radar screens and infra-red detection. The difficulty in developing successful fundamental research in such a field as luminescence in solids is largely due to lack of broad scientific perspective. The complicated nature of the phenomena makes it difficult for a theoretician to select significant experimental data and the experimentalist, who alone appreciates the significance of the many minor technical details, is often unable to connect them usefully with theoretical ideas. Progress in a confused and complicated subject such as electronic processes in solids is made largely by efforts to integrate the subject phenomenologically by varying significantly many variables in experiments. The classic researches of Pohl, Hilsch, etc., on conduction in alkali halides is work of this sort. At the other extreme we have those workers in the field of luminescent solids who continue to accumulate unrepresentative experimental data and attempt to make it fit mathematical relationships.

The first five papers in the symposium deal with the production of phosphors under industrial conditions, the products being of very high purity and produced in a carefully controlled way which is not always possible in more academic laboratories. It is only by such methods that really reproducible materials can be obtained and the requirement that experiments are capable of repetition can be satisfied. The demand also for materials with a wide range of special qualities has resulted, after much effort, in a large number of new phosphors of special type being produced. The availability of these phosphors often makes possible experiments of a fundamental nature which were previously impracticable. Thus the application of luminescence benefits fundamental research, but the discussion at the conference shows clearly that it is realised also that research is hindered by preoccupation with certain materials of practical importance, but which are not amenable to fundamental analysis, and with phenomena which are not capable of interpretation. It is interesting to note that the work of Pohl and his school began on the well-known zinc sulphide phosphors, but obtained the greatest success when attention was concentrated on the more convenient synthetic alkali halide crystals, which were then of no practical importance but which, after development by Pohl, have later become of considerable technical importance.

The symposium includes several interesting papers describing war work on phosphors for use as infra-red detectors, and the early work on infra-red properties of phosphors has now been added to considerably. Though absorption and excitation properties of phosphors have been studied, infra-red emission is still neglected. Comparable widening of interest in the properties of phosphors has been caused lately by the demand, for medical purposes, of phosphors emitting ultra-violet light.

It is clear from the symposium that the breadth of approach to luminescence in solids is widening, X-ray diffraction is now a standard method for studying structure and good quantitative spectroscopy is now in general use. New methods involving study of magnetic susceptibility, polarisation of luminescence, etc., were discussed. Since the symposium, development of scintillation counters for nuclear particles has brought a new set of workers with new methods into the field. Also one can expect the electron microscope and radioactive tracers to give useful information about the formation of micro-crystalline phosphors by solid reaction. It was clearly realised at the

conference that one of the main weaknesses of the subject was lack of understanding of how phosphors are produced. While it has been usual for semiconductors to be produced under conditions which were understood and which were known to produce stoichiometric deviations, comparable experiments on phosphors were lacking though workers had much recourse to the idea of stoichiometric defect or excess.

There was also a feeling that, in order to obtain quantitative absorption data, etc., on phosphors, alkali halide type phosphors with large crystal size should be used. Unfortunately most phosphors have absorption coefficients too high to be measured in macroscopic crystals. During the last year microspectrographic methods, which have been used by biologists for many years, have been applied by the Leningrad school to ordinary microcrystalline phosphors. Quantitative data on absorption curves and coefficients, on dichroism and polarisation of luminescence can be obtained on single micro-crystals. Availability of reflecting microscopes in this country makes such work relatively simple and procedures of this nature hold much promise for the future.

M. H. F. W.

Luminescent Materials. By G. F. J. GARLICK. [Pp. viii + 254, with 127 figures.] (Oxford: at the Clarendon Press, 1949. 21s. net.)

THIS monograph supplies a long-felt need for an authoritative and unified account of recent advances made in the study of solid luminescent materials. The author, who has himself made notable contributions to the subject, has adopted the wholly academic approach in this book. The commercial and military uses of luminescent materials are referred to only incidentally, and the author concentrates his attention on the physical properties of the various classes of phosphors and sets himself the aim of reducing the observed phenomena to simple interpretation in terms of idealised models. In this attempt he exhibits a well-balanced judgment among the complex evidence and conflicting views of other investigators, but, as he is forced to admit, there remain many gaps to be filled before a clear picture is to be obtained. The following fundamental questions still remain incompletely answered for common phosphors : (a) the precise nature of the emission centre, (b) whether the activator is in solid solution or in interstitial positions in the crystal, (c) the variation of emission efficiency with excitation intensity, (d) the nature of electron traps, their relation to the emission centres, and the reasons for their distributions in depth, and (e) the effect of secondary activators in releasing stored luminescence under the influence of infra-red light. It is not improbable that newer concepts on imperfections and dislocations in crystals may lead to solutions of these problems, and ultimately enable one to interpret the phenomena of luminescence by reference to atomic positions in the solid.

The book is one of a series of Monographs on the Physics and Chemistry of Materials issued by the Clarendon Press, and fully maintains the high standards of the University Press in content and in production.

E. J. B.

A New Notation and Enumeration System for Organic Compounds. By G. MALCOLM DYSON, M.A., D.Sc., Ph.D., F.R.I.C. Second edition. [Pp. x + 138.] (London, New York, Toronto : Longmans, Green & Co., 1949. 10s. 6d. net.)

THE first edition of this monograph (1947) has now been subject to almost international consideration and criticism. The main changes have arisen from consultations between the author and American chemists in connection with ring-systems, for example, in relation to the Patterson Ring-Index. A fundamental re-ordering of some symbols has also been made, 4, 5C4 for example becoming C₄, 4,5 this change facilitating subsequent mechanical operations, including indexing. It is interesting to find that a scheme originally so complete in itself can be improved by constructive criticism from enthusiasts in nomenclature. A lesser scheme might well have been unable to assimilate change. Dr. Dyson is to be congratulated.

E. E. TURNER.

Recent Advances in Analytical Chemistry. Edited by R. E. BURK and O. GRUMMITT. Frontiers in Chemistry, Vol. VII. [Pp. xii + 209, with 93 figures.] (New York and London : Interscience Publishers, Inc., 1949. 36s. net.)

THE practitioner in any branch of science has difficulty in keeping pace with modern developments. This is particularly true of the analytical chemist, who finds it necessary nowadays to be prepared to adopt methods once regarded as tools exclusive to the physicist or biologist. Without them he cannot obtain information supplemental to that obtained by chemical methods and necessary for elucidation of his problems. Even in the strictly chemical field no one can be a pure inorganic or pure organic chemist and yet be up to date. For these reasons any book on recent advances in analytical procedure is welcome as it enables the practitioner to see how the newer methods can be adopted to his particular needs.

The present volume is restricted to those newer advances which apply physico-chemical and chemical methods. The material was first given in a lecture series held at Western Reserve University and hence has the advantages and the disadvantages of subjects prepared for a particular audience. The essential theory is outlined and particular applications given ; but all the important developments cannot be included. This is not serious, as the interested reader can grasp the potentialities of each method, and if his curiosity is sufficiently aroused he will be able to find references to the omissions and details of any specialised techniques.

The subjects covered, with their authors, are Polarography and Amperometric Titrations (Kolthoff), Inorganic Analysis with Organic Reagents (Yoe), Recent Colorimetric and Gravimetric Organic Reagents (Yoe), Infrared Spectroscopy (Boeck), Electron Microscopy and Microanalysis (Hillier), Fractionation, Analysis and Purification of Hydrocarbons (Rossini) and the Mass Spectrometer (Hipple).

No one can be really expert in all the fields mentioned. But every analytical chemist should be aware of what is being developed and should know enough of the scope of particular methods to determine when they are worth considering for any unusual problem. Lest the cost of some of the equipment be regarded as too high, it is worth quoting one of the authors who says " these methods are of a fundamental nature and can afford to be used

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only upon materials the value of which is such as to warrant the cost of research examination. Once the composition of an unknown mixture . . . is disclosed by the fundamental investigations, more rapid and less costly methods can usually be devised for the routine examination of other samples of similar material."

J. R. NICHOLLS.

Thorpe's Dictionary of Applied Chemistry. Vol. IX : Oils, Fatty—Pituitary Body. Fourth edition. [Pp. xviii + 671, illustrated.] (London, New York, Toronto : Longmans, Green & Co., 1949. 80s. net.)

IT is a pleasure to pick up and read this volume of Thorpe at random, containing, as it does, so many topics of general interest.

The longest article is on Petroleum by Dr. G. Egloff. The figures he gives show that in 1944 the United States was producing 64 per cent. of the world's output. His article is exhaustive from the American viewpoint, but a feeling is left that a British author would have done more justice to our own contributions to the science.

Fats and fatty oils are dealt with in a monograph by Prof. T. P. Hilditch and are therefore authoritative on the chemistry of the subject. The analytical side is dealt with by Dr. K. A. Williams. The designer of an oil-seed extraction plant or of a modern fatty acid still will, however, look in vain for much useful information.

The subject of photography is covered by C. H. Smith and T. H. Jones of Kodak in a well-written form and gains from being preceded by Photochemistry by Dr. E. J. Bowen and followed by Photosensitivity of Dyestuffs by Drs. E. H. Rodd and E. B. Abbott. The last-named authors point out that, despite its technical importance, there is no comprehensive account in any text-book on the fading of dyestuffs, and they certainly make up this deficiency.

The amount of material available on Penicillin is surprising and is well written by a team from Glaxo. They stress indirectly the importance of close collaboration between the chemical engineer and the bacteriologist if economic production is to be ensured.

Phase Rule is covered in a refreshing article by L. M. Hill of Northwich. A new era has been introduced in this subject by showing that, apart from using it as a means of classifying information, it can provide a good guide for the operation of industrial processes which would otherwise be of a very empirical nature. The clarity of exposition has not been well served by the method of layout of the text and diagrams—a fault which to some extent is inherent in the format adopted.

Order-Disorder Transformations in Alloys by Dr. A. J. Bradley deals with the effect of statistical or of regular distribution of atoms in alloy lattice structure. The subject has very interesting possibilities and presumably has been fitted in here because it is a recent development but will, in future, be dealt with under Alloys.

The article on Papermaking is adequate, but does not come up to the high standards of the others. It contains no references which might enable those interested in the subject to follow up the necessarily brief information in the space available. The two pictures of rag boilers serve little useful purpose and would be of no assistance to a designer.

Prof. H. T. S. Britton contributes on both " p_H " and Oxidation-Reduction Potentials. He draws attention to the anomalies which are creeping in owing to the adoption of either the classical Arrhenius theory or activity concepts. Information on the Parachor is summarised by Prof. S. Sugden.

Other articles include Pigments and Paints, Pest Control, Perfumes, Overpotential and Passivity, Oxidizing Enzymes, Opium, Osmosis, Particle Size Measurement, etc. In fact, something for every taste and all well worth reading. M. B. DONALD.

Synthetic Perfumes. By T. F. WEST, D.Sc., Ph.D., A.M.I.Chem.E., F.R.I.C., H. J. STRAUSZ, Dr.Phil., M.A., F.R.I.C., and D. H. R. BARTON, Ph.D., D.I.C., F.R.I.C. [Pp. viii + 380.] (London : Edward Arnold & Co., 1949. 70s. net.)

MIXTURES of synthetic chemicals alone are invariably lacking in certain desirable odorous properties, which can only be provided by the addition of small amounts of natural perfumes. This observation, combined with the unsolved scientific problems connected with the blending, maturing and fixation of perfumes and the possible relationships between contribution and odour, illustrates that the production of a synthetic perfume is very largely an art at the present day. *Synthetic Perfumes* renders valuable service in drawing attention to these problems, but it regards a more detailed description of perfumery as being beyond the scope of the present work, which, as stated in the preface, is written primarily from the organic chemical point of view.

The book contains an excellent account of the methods available for the preparation of the main hydrocarbons, alcohols, aldehydes, ketones, lactones, ethers, esters, phenols, acetals, and nitrogenous compounds employed in the perfume industry. The treatment is full and up-to-date, numerous references are included, the print and formulæ are clear, and a useful list of trade names of perfumery materials, with their constitution and odour characteristics, is appended. The text is accurate and free from serious errors, and, whilst the work will be most useful to perfume technologists on account of the valuable collection of chemical and physical information of perfumery materials, other students will discover much of interest in connection with the odorous properties of the substances described.

The price of 70s. is, however, extremely severe for a work of 380 pages. R. D. H.

Monomers. Edited by E. R. BLOUT, W. P. HOHENSTEIN and H. MARK. [Pp. 374 (loose-leaf), with numerous figures.] (New York and London : Interscience Publishers, Inc., 1949. 60s. net.)

THIS is a very useful " collection of data and procedures on the basic materials for the synthesis of fibres, plastics and rubbers," and consists of eight sections by experts on the following substances : Acrylonitrile, butadiene, *iso*butylene, isoprene, methyl methacrylate, styrene, vinyl acetate and vinyl chloride. The scheme of treatment for each of these compounds is as follows : Introduction, production (laboratory and large-scale), analysis, physical constants, chemical reactions, and polymerisation, ample references being provided. The treatment is clear and concise and the volume will be of value not only to those chemists concerned with polymers, but also to all those interested in the " monomers." E. E. TURNER.

Metallic Creep and Creep Resistant Alloys. By A. H. SULLY, M.Sc., Ph.D. [Pp. xii + 278, with 138 figures.] (London : Butterworth's Scientific Publications, 1949. 25s. net.)

THE introduction of the gas turbine engine has stimulated great interest in the development of alloys capable of withstanding high stresses for prolonged periods at high temperatures. So far, the main demand has come from the aircraft industry. Very far-reaching applications in other directions are to be expected however, because, if the working temperatures of engines can be increased, it will be possible to convert fuel into power more efficiently. As Dr. Allen says in his foreword to the book under review, " it is the possibilities in this direction that appeal to the imagination. . . . A large improvement in the average efficiency of power production would be as important as the discovery of several major coal or oil fields."

The importance of metallic creep is thus obvious. In his excellent and timely book on this subject, Dr. Sully gives a well-balanced survey of both the scientific and practical aspects. Chapters are included on the measurement of creep, on the characteristics of creep curves and on metallurgical factors affecting creep. Physical theories of creep are explained in some detail, including the recent dislocation theories. While admiring Dr. Sully's up-to-date account of the theoretical work, the reviewer was a little sorry to see the old recovery theory of creep treated rather summarily. Surely the idea that recovery can balance strain hardening and thereby make the creep rate constant is too sound to be relegated to the home for aged theories ?

The survey of the creep properties of various alloys, in the final chapters, will be very useful to those concerned with developing creep-resistant materials, as it collects together much of the enormous amount of recent work in this field. It should also be studied by all who are working on the physics of creep ; specimens containing ten alloying elements, and extending only a few atomic spacings per hour, suggest creep problems rather remote from those usually considered by academic investigators to-day, problems which may need a new theoretical approach.

<div align="right">A. H. COTTRELL.</div>

The Practice of Research in the Chemical Industries. By R. H, GRIFFITH. [Pp. viii + 184.] (London : Oxford University Press, 1949. 12s. 6d. net.)

REGARDING the importance of continuous organised research in industry there is but one opinion, but there is still room for much discussion and diversity of opinion on the organisation and administration of such research. American technical journals in particular reveal the intense interest prevailing in the U.S.A., giving much space to discussions on the technique of research management and on related topics. Large-scale industrial research is still so novel, scarcely covering the average industrial life of one man, that it is itself scarcely out of the experimental stage. Mr. Griffith's book should attract many readers amongst those whose task it is to direct research, on however large or small a scale, and it can be recommended also to be read by the youngest recruit to industrial research, who cannot too soon begin to understand the relation of his modest part to the whole undertaking. The author, drawing largely on his own experience, is mainly concerned with the conduct of industrial chemical research on a considerable scale, considering that an efficient research department requires a minimum of some twenty

scientific staff and an expenditure of not less than £40,000 per annum, besides having at call a staff of engineers. It must be remembered, however, that there are a large number of smaller firms which have, or might have, more modest but quite successful research departments. A conference in Manchester in 1948, organised by the Manchester Joint Research Council, gave them an opportunity to ventilate some of their problems. (Their needs are not entirely met by the Research Associations, the functions of which are dealt with by Dr. D. W. Hill of the Shirley Institute in a book quoted by Mr. Griffith.) An essay could be written on any one of Mr. Griffith's highly condensed chapters, which discuss such widely different topics as the functions of the research department and its relation to other departments ; the choice of staff and their treatment ; the literature and the library ; and the choice and definition of research programmes, passing on to the very practical topics of the design of the laboratory and the technique of research from the small scale, through the pilot plant to full scale development. A chapter on " operational research " deals with the function of the research department in checking performance in current processes. Though much of the subject matter is fairly common knowledge, and Mr. Griffith modestly disclaims any novelty in what he writes, most readers should find in it something they have forgotten or some point of view worth their attention. The book is well printed and a pleasure to read.

<div align="right">E. H. R.</div>

GEOLOGY

The Middle Silurian Rocks of North Wales. By P. G. H. BOSWELL, A.R.C.S., D.Sc., F.R.S. [Pp. xvi + 448, with 25 plates and 107 text-figures and folders.] (London : Edward Arnold & Co., 1949. 80s. net.)

GEOLOGICALLY, North Wales is still in part *terra incognita*. Ramsay's original memoir of the work of the Geological Survey during the latter half of the nineteenth century, *The Geology of North Wales*, continues to remain for considerable areas the only published information on the stratigraphy and structure of the Lower Palæozoic rocks : and in its 330 pages only five pages are devoted, as Prof. Boswell points out, to the " Middle and Upper Silurian rocks." It is Prof. Boswell's purpose, admirably fulfilled, to extend and fill out the work of the primary survey—in a sense to provide a supplement to Ramsay's great volume—on the Silurian country east of the River Conway and north of the River Dee. Himself the author or joint-author of sixteen publications on the area during the past quarter-century, Prof. Boswell now presents us with a conspective account of the rocks of Wenlock and Ludlow age which crop out extensively in the Denbighshire uplands and the Clwydian hills.

His book is essentially a compendium and a book of reference. In it he amplifies and elaborates the several accounts earlier given by himself and his colleagues in a number of scattered papers ; and with a wealth of added detail welds them into a coherent unity that allows him to make illuminating generalisations on stratigraphy and structure. Less important sections include comments on the superficial deposits, the economic resources, and the water supply of the area.

Most of Part I, occupying about a third of the book, contains very full

descriptions of the general stratigraphy of the area, of the lithological and palæontological characters of the successive zones, and of the palæogeographical deductions to be drawn from changes in rock-types and from lateral variations in the stratigraphical succession. The general picture emerging is that of deposition of shallow-water marine sediments—muds, silts, and sands—accumulating in places to a thickness of about 7000 ft. in a region undergoing pulsatory subsidence. There are indications of the proximity of a land-mass towards the north-west; and some of the sediments may provide evidence of a contemporary arid climate and of climatic oscillations.

The chapter on structure is an expression of the author's views on mapping technique. He makes clear how difficult it is to determine marker horizons in rocks which in zonal succession never show strong contrasts, especially when any one zone may display notable variations in lithology in comparatively short distances. The use of graptolites for zonal diagnosis is then important, and the interpretation of structure offered acknowledges that fact. The differing views put forward by O. T. Jones are dismissed rather lightly; and the reader might have expected a synthesis of those elements of slump tectonics which Prof. Boswell is prepared to accept and the more orthodox structures which he mostly favours. In particular, some of Jones's maps might have been reproduced, if only as matter for criticism. In the interpretation of the fault pattern, the author discusses the possible effects of torsion and of shear—while stressing the speculative nature of many faults that are surmised to exist in country displaying few outcrops and fewer contacts. He describes the paradox of the Clwydian hills—a horst with synclinal internal structure.

The remaining two-thirds of the book, forming Part II, is a detailed account of the geology of the different districts within the region covered. Almost every outcrop is referred to, and the mass of information is a measure of the extreme thoroughness and persistence with which Prof. Boswell has carried out his work. As a result, this particular area of North Wales is now as completely known as any area in Britain; and Prof. Boswell has provided an invaluable and minutely documented guide for the use of the visiting geologist, the regional planner, and the civil engineer.

The plates of photographs, which include some of great scenic beauty, materially contribute to an understanding of the text; but they vary greatly in quality and much of their value is too often lost by mediocre photography—some are quite out of focus, and are a blemish on the book.

It is a pity the price of the book will put it out of the reach of a great many people, especially students, who would otherwise wish to have it on their shelves. The high cost must partly be put down to the many maps included as folding plates. In themselves the maps are highly informative, and are a very necessary and valuable part of the book's contents: they are also well drawn and clear, and contribute to the intrinsic quality of the book. But most of them could without notable loss of detail have been appreciably reduced in scale; and many of them, nearly a half, could then have fitted into a page with consequent saving on folders. The maps show a wide range of scales: in those drawn to scales of 4 in. to 1 mile and under, no less than thirteen different scales are employed: this makes the fitting together of maps of neighbouring areas very inconvenient, especially as some of the scales have the awkward ratios of $\frac{3}{4}$ in., $1\frac{9}{16}$ in., and $1\frac{3}{4}$ in. to 1 mile. Many of the maps are taken unchanged from sundry incidental publications: Prof. Boswell's own synthesis of the several maps of other workers would have been

welcome, and might well have been included as a general geological map of the area—of which there is a lack.

It is graceless to over-emphasise comparatively minor defects. The book is, and will remain for many years, the standard work on the area ; and whatever future discoveries may be made will find themselves set in the comprehensive framework created by Prof. Boswell. He has written the book with obvious pleasure ; and there runs through it a tone of personal delight and excitement that must echo his feelings as a geologist in the field, and that makes it a book as stimulating for the neophyte as it is informative for the professional. It is strongly to be recommended, and should be in every geologist's library.

T. N. G.

Outline of Historical Geology. By A. K. WELLS, D.Sc. Second edition, revised with the assistance of J. F. KIRKALDY, D.Sc. [Pp. xvi + 356, with 2 plates and 124 figures.] (London : Thomas Murby & Co., 1948. 25s. net.)

THIS book was originally written to provide the intelligent citizen and the student beginning a course in geology with an account of the subject that should stress its historical and cultural sides. To this end the book was written as a continuous narrative, and technical terms were eschewed as far as was possible.

In the present edition these aims are still prominent, but the scope of the book has been enlarged so as to make it suitable for students reading for Degrees. The philosophical rather than the factual aspects of stratigraphy have been emphasised, and a number of typical stratigraphical problems have been discussed.

The principal criticism that may be offered is that the Pre-Cambrian, which occupies at least two-thirds of geological time, is only cursorily treated in a short chapter, on the ground that its rocks contain no fossils and it is therefore unsuitable for illustrating the principles of historical geology. From this dubious standpoint the Pre-Cambrian is merely the huge foundation on which the Cambrian and later fossiliferous formations rest. Consequently a brief and perfunctory account is inserted as Chap. VI after the treatment of the Caledonian Revolution. In the reviewer's opinion this procedure impairs the clarity of the story, which is otherwise simply and brilliantly told. Summarily dismissing two-thirds of the geological story, and treating it in this sequence, is like beginning English history in B.C. 55, and inserting an account of Pre-Roman times after the Norman Conquest. The book would gain in perspicuity by restoring the Pre-Cambrian chapter to its rightful place at the beginning of the story.

A short list of selected references for further reading is appended to most chapters. The style, illustrations, and index are excellent. The book is suitable, not only for the University student, but also for students who attend W.E.A. and other adult classes in geology. The authors have shown that what is often a " dreich " subject (to use an expressive Scotticism) in the classroom can be made into one of the most fascinating chapters of geology.

G. W. T.

Physical Geology. By CHESTER R. LONGWELL, ADOLPH KNOPF, and RICHARD F. FLINT. Third edition. [Pp. xviii + 602, with frontispiece and 365 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall Ltd., 1948. 40s. net.)

THE first edition of this work (1932) was reviewed in SCIENCE PROGRESS, XXVIII, 1934, 556. The second edition (1939) escaped review because of the war-time stoppage of publication of this journal. In the present edition a new unit, Chapter II, on "The Method and Scope of Geologic Study," has been added, the entire text has been critically reviewed, sections of many chapters have been reorganised and recast, and new concepts and data have been incorporated into the text. A number of topics relating to crustal movement have been relegated to the new chapter, e.g. isostatic balance of the earth's crust in relation to deformation, continents and earth movements, and the inter-relations between external and internal forces. A special word of praise must be accorded to the magnificent illustrations, which are largely new.

This book inevitably challenges comparison with A. Holmes's recent *Principles of Physical Geology*, on this side of the Atlantic at least. The two texts cover much the same field of study, both are very finely illustrated, and are written in such a way as to compel (as we think) the absorbed attention of serious students. But in Holmes there is a somewhat more pronounced emphasis on the results of the internal forces of the earth. In the work under review the authors do not go as deeply as Holmes into internal forces, and pay more detailed attention to the modelling of the earth's surface by external forces. The student will have considerable difficulty in choosing between two excellent works, if he has to make a choice.

Notwithstanding the explanation advanced on the dust cover of the book, we still fail to appreciate the reasons for the three appendices on Minerals, Rocks, and Topographic Maps, which are really not much more than glossaries. Surely these subjects are treated more fully in separate texts for the purposes of first-year classes in American colleges?

<div align="right">G. W. T.</div>

The Geology of Water Supply. By SIR CYRIL S. FOX, D.Sc., M.I.Min.E., F.G.S. [Pp. x + 209, with 15 plates and 49 figures.] (London: The Technical Press, Ltd., 1949. 25s. net.)

THE author has here given us a most readable account of some of the aspects of water supply (and of many other matters), abounding in quotations, a number of which are lengthy and historical. His book will doubtless interest particularly those who are acquainted with India and the Middle East. The bearing of much of the information on the practical questions of water supply is not always discernible, and Sir Cyril Fox seems to have been rather out of touch with modern waterworks practice and the many different types of problems in which geological aid is now sought. Whilst the somewhat idealised treatment of the geology of impounding reservoirs, shallow wells and irrigation will continue to be of value as exemplifying geological principles, the hydrogeologist or water engineer in the larger communities of the English-speaking world will find little up-to-date information on other aspects of the subject, and some tends to be rather misleading. Most of the references to literature date from long ago: excepting that to F. Dixey's

book (1931), the latest publication on water supply referred to is dated 1924.

The volume is illustrated by many beautiful photographs, all apparently from India. P. G. H. BOSWELL.

BOTANY

Fungi and Plant Disease. By B. B. MUNDKUR, M.A., Ph.D., F.N.I. [Pp. x + 246, with 130 figures.] (London : Macmillan & Co., Ltd., 1949. 16s. net.)

IN such subjects as Chemistry and Physics there is no inherent reason why text-books written in Britain should not be as suitable for Indian students as for British. The material of Physics and Chemistry is universal. But in Botany, although the principles of the subject hold good the world over, the material used in their illustration must vary from place to place, since the flora of one part of the world may be quite different from that of another. It is, therefore, very necessary that each major country should have its own botanical text-books based on the native flora. Dr. Mundkur's book should, in consequence, be a most valuable addition to the books used by Indian students studying mycology and plant pathology in the Universities and Agricultural Colleges.

The plan of the book is clear and logical. A first chapter on morphology and reproduction in fungi introduces the principal terms used in mycology. Chapters follow on physiology of fungi, types of disease caused by fungal pathogens, methods of phytopathological investigation, and mycological nomenclature. Then each major group of fungi is considered separately— a general discussion of morphology and taxonomy being followed by excellent descriptions of diseases of importance in India caused by pathogens belonging to the group. Finally, there are brief chapters on bacteria as plant pathogens, virus diseases, and methods of disease control.

Naturally there are a number of points that call for criticism. We read that " the osmotic value of fungal cells is higher than that of the host cells, so that they are able to absorb food from them easily "—which is physiologically absurd. *Mucor hiemalis* is given as an example of a homothallic mould, and we are told that *Psalliota campestris* (the mushroom) is " the most highly organized fungus in Eumycetes "—a veritable *Homo sapiens* of the Fungal Kingdom ! But the book as a whole is distinctly good and easy to read, since the style is simple and direct. For the most part the illustrations are of high quality, but Fig. 102, a diagram of heterothallism in a rust, is very misleading.

Dr. Mundkur's book should become a standard work in India and the small blemishes can be removed in later editions, but it is essentially a text-book for the Indian student and would be of little value to mycological students in Britain. C. T. INGOLD.

The Periodic Partial Failures of American Cottons ; their Causes and Remedies. By R. H. DASTUR. Second edition. [Pp. xii + 172, with 30 figures.] (Bombay : Indian Central Cotton Committee, 1949. Rs.6.-.)

AMERICAN cotton in various parts of Pakistan and India has been liable to give occasional poor crops on account of two physiological diseases. Their

nature and suitable remedial measures are fully described in this monograph by Prof. R. H. Dastur. Even those not directly interested in cotton will find the account provides ample illustration of the difficulties inherent in investigating crop failures caused by physiological disorders.

The main portion, covering the scope of the first edition, describes the disease known as tirak which in the Punjab has sometimes caused yields to be as low as a quarter of the normal level. Typical symptoms are discoloration of the leaves and early defoliation, premature opening of bolls with immature seeds and low fibre quality. Detailed studies led to the conclusion that tirak arises when the growth phases of the crop are physiologically unbalanced, when vegetative growth is in excess of that produced in the form of bolls. Tirak may occur on two particular soil types, light sandy soils deficient in nitrogen and soils containing free sodium salts or sodium clay in the subsoil. In both instances low potash content is the source of the trouble. On light sandy soils the uptake of potash is reduced by shortage of nitrogen ; on saline subsoils physiological drought interferes with the normal uptake of nutrient minerals. The application of nitrogenous fertilisers at an appropriate stage of plant growth successfully prevents tirak caused by nitrogen starvation, whilst on saline subsoils extra irrigation from flowering time enables the top soil to meet the water requirements. In both instances, however, the simple remedy of late sowing effectively reduces tirak because the plant is able to function with less nitrogen or meet its own water requirements. The reduced yield from the smaller plants of late sowings was successfully counterbalanced by closer spacing. Subsequent work in the Sind indicated the same causes and remedy for " bad opening " of cotton bolls as previously found in the Punjab.

The second edition also includes the results of investigations into the more prevalent of two forms of red leaf disease, another instance where the interaction of a soil factor and a climatic factor produces a physiological disease. Remedial measures for lessening the intensity and spread were successfully formulated.

E. LORD.

ZOOLOGY

The Classification of Animals. By W. T. CALMAN, C.B., D.Sc., LL.D., F.R.S. [Pp. viii + 54.] (London : Methuen & Co., Ltd., 1949. 4s. 6d. net.)

THIS little book is subtitled " An Introduction to Zoological Taxonomy," and the name of its author is a sufficient indication that it is authoritative in its field. But to read it is to be disappointed. It is, indeed, faithful to its title so long as the reader believes that a true introduction to a branch of science is to be found in a statement of facts and conventions that have gained the respectability of long usage. Dr. Calman seems to take the view that to discuss also those problems that are in the front line of taxonomic studies is to confuse the reader. This is all the more disappointing since we are accustomed to find in the series of Monographs on Biological Subjects, to which this is the latest addition, works which fulfil the publishers' promise. This is that they shall be " authoritative accounts of the present state of knowledge in various departments of Biology " and books in which " the general reader with a taste for biology will be able to follow the most recent

developments in the various branches of the science." It is to be hoped that the Editors of the series have not changed their policy.

The reader will find here, clearly stated and concisely, all those facts which he should assimilate before he begins to *think* about taxonomy. But there is no guidance as to how he should think. Thus, at the end of a paragraph on " clines " the author writes : " Here again, while clines are important objects of study, not to be overlooked by the systematist, nothing would be gained by attempting to incorporate them into the classification or nomenclature in which it is expressed." This is very true, but its complacency might be seriously misleading to a reader who had no other knowledge of the hidden problems involved. We must look forward to a volume in which Dr. Calman will allow himself to pursue the problems that he felt obliged to exclude from the narrow limits of the present work.

W. H.

On Indian Insect Types. Edited by Dr. M. B. MIRZA. I : External and Internal Anatomy of the Buffalo-louse, *Hæmatopinus tuberculatus* Burmeister. By M. A. H. QADRI, M.Sc., Ph.D. (Alig.), Ph.D. (Cantab.), F.R.E.S., F.Z.S. (London). [Pp. x + 21, with 9 plates.] (India : Aligarh Muslim University Publications (Zoological Series), 1948. Rs.3.-.)

THE Editor proposes to publish a series of monographs on Indian insects, which provide an immense range of material of great potential interest. There can be no question of the value of such a series.

The present monograph is the first and deals with a common insect, the louse of the buffalo. If, as we suppose, it is intended to be used in part by the applied entomologist, it is perhaps to be regretted that the author limits himself to anatomy ; after all, it is the living animal and its potential multiplication which form the core of a problem in applied biology.

One might perhaps feel that the student would grasp the subject more easily if the author had provided a general figure showing the relation of the internal organs to one another. Many of the figures illustrate small fragments and it is not easy even for the expert reader to know just where they come in relation to other structures. We feel that the monograph, even as an account of anatomy, is not sufficiently complete. It is not easy for the reader to discover how one would distinguish the two sexes : there is no mention of the mycetome (which may be supposed to be a conspicuous and characteristic organ) : we are not told whether eyes are present or absent : there is no account of growth or mention of the early instars. The author holds original views on the homologies of the mouthparts, but in putting them forward does not relate them to what is known of the embryology of these structures in other lice. The monograph contains a number of somewhat unsatisfactory statements, *e.g.* " The head is tolerably well developed."

P. A. BUXTON.

The Philosophy and Practice of Bee-Keeping. By A. L. GREGG, M.A., M.D., M.Ch. [Pp. 240, with frontispiece and 28 figures, including 10 plates.] (Bee Craft, Ltd., " Bracken Dene," Manor Way, Petts Wood, Kent, 1949. 12s. 6d. net.)

THIS book does not attempt to cover the whole art of bee-keeping, but a bee-keeper of some experience will derive acute pleasure and great profit

from it. Many aspects, some carefully avoided by other authors, are discussed in a style which shows accurate and patient observation and careful deduction. Accepted practice and the author's few deviations from it are explained in a thorough and thought-provoking way, and with an easy wit.

The reviewer was delighted to find the whole of Dr. Gregg's celebrated lecture on Colony Population with the relevant curves. This analysis should become a classic, and detailed study and clear understanding will be of great value to any bee-keeper. The reading of the chapter would be made much easier if the graphs and tables were made extensible outside the book and placed at the end.

It seems a pity that the NOLAN-discredited figure of 3000 eggs per day should be used in the chapter on brood-chamber capacity, particularly as the accepted figure of 1800 is used in the discussion on Colony Population. This discrepancy is very obvious, and should be resolved in the later editions. If an allowance be made for stores, which can be estimated as about one-third of the cell capacity, the same conclusion on brood chamber size will be reached.

One would also have liked to see under " Library " two books, Herrod Hempsall's *Beekeeping New and Old*, full of still useful knowledge, and *Golden Throng* by Teale, with its wonderful photographs.

Finally, will not the publishers consider a better paper and binding ? The mechanical makeup of this first edition is unworthy of the subject and its treatment.

This book is just what one would have expected from the pen of Dr. Gregg, and one can pay book and author no higher compliment. It is a most excellent and worthwhile addition to bee-keeping literature.

<div align="right">E. F. W.</div>

Bees and Honey. By GEORGE A. CARTER, B.Sc., A.R.I.C. Third edition.
[Pp. 115, with 13 plates.] (Bee Craft, Ltd., " Bracken Dene," Manor Way, Petts Wood, Kent. 5s. 6d. net.)

THIS book is small and suffers by reason of its smallness.

The section on Honey is sound and gives the impression of practical knowledge which the part on Bees does not, as several statements are made which the author has apparently not checked. For instance, a queenless stock, conditioned to gathering pollen, continues to do so ; in fact, a queenless stock often gathers more than a queenright stock, as stores pile up due to brood vanishing. The description of the queenright hiss is quite inaccurate. The reaction of a healthy colony to a knock is a short hiss, not a buzz, of complex composition, but in the 4000- to 5000-cycle region, starting abruptly, lasting for ⅛ to ¼ second and ceasing, not varying appreciably in pitch. The difficult and unpredictable art of queen introduction, covered by Doolittle in several chapters of many thousand words and by Snelgrove in a volume, is airily dismissed by the author in two pages of 600 words, leaving any novice in a most dangerous state of complacency when facing this task. The Langstroth hive is, by inference, quoted as a single-brood-chamber, which even in this country it is not. Only the M.D. can be so described.

The compilation is amateurish. More than half of " Wintering " is devoted to Summer management ; Emergency Feeding, an essential part of Wintering, is discussed later : there is more about manipulation under

the section on hives than under " Manipulation " ; the Sulfa treatment is not under Diseases, but under Chemicals.

In a book of 100-odd pages a notebook style would be permissible, even welcome ; redundancy would not. Yet Rothamsted's opinion on salt in water is given twice, and so is the composition of Frow, and the use of candy.

The last chapter is worthless. A little about von Frisch is mentioned earlier, but his 1921–23 work, not the later, which is quite different. Surely in a chapter on the Bee-Mind von Frisch should have a place.

<div align="right">E. F. W.</div>

PHYSIOLOGY, BIOCHEMISTRY AND MEDICINE

Annual Review of Physiology. Vol. XI. VICTOR E. HALL, Editor, JEFFERSON M. CRIMSON and ARTHUR C. GIESE, Associate Editors. [Pp. x + 643.] (Stanford, California : Annual Reviews, Inc., and the American Physiological Society, 1949. $6.00.)

IN their preface to this volume, the editors remark that " the problem of publishing annually a volume of standard size purporting to review the current developments in physiology, when these are expanding in geometric progression, is one requiring continuous adaptation." This they have achieved by omitting certain topics now covered by other reviews, and by " pleading with reviewers " to consider only papers of noteworthy importance, reducing coverage of others to mere listing. Applied physiology, physiological psychology and pathological topics will henceforth disappear, and increased space thereby be made available for the conventional subdivisions of physiology. That the reviewers have taken the editors' pleadings to heart is apparent when most of the chapters are compared with their predecessors ; but there is still a tendency towards what Teorell, in his excellently written article on " Permeability," refers to as " monotonous recitations of the products of the year's work," couched moreover in terms intelligible only to the expert in that particular field, who will probably not need to be introduced to the year's advances in his subject. All but three of the twenty-two chapters are of American origin ; outstanding contributions come from Phillips (Kidney), Moe and Shideman (Pharmacology), Magoun (Somatic functions of the nervous system) and the Walters (Electrical activity of the brain).

<div align="right">R. A. GREGORY.</div>

Conditioned Reflexes and Neuron Organization. By JERZY KONORSKI. Translated from the Polish MS. under the author's supervision by STEPHEN GARRY. [Pp. xiv + 267, with 18 figures.] (Cambridge : at the University Press, 1948. 18s. net.)

WHAT really happens when a dog salivates in response to the ringing of a bell no longer accompanied by food ? Why does the salivation fail after several trials without food, and how is it at once restored if some indifferent stimulus is combined with the bell ? Pavlov's hundredth birthday, which falls this year, renews his challenge to come to terms with a great corpus of scientific fact and with the theory by which he collected and systematised it.

Prof. Konorski's book is doubly helpful. It gives Pavlov's main results and then attempts, with originality and vigour, to bring them into relation with modern ideas of the functioning of nerve tissue. The descriptive parts make heavy reading because Pavlovian language, although unambiguous,

takes time to learn ; it tends to obscure the clear-cut, simple nature of these brilliant observations. A chapter on nomenclature is most helpful in drawing the threads together. Of Pavlov's theories it is made clear that they have nothing in common with the neurophysiology of to-day, and their internal contradictions are exposed with ruthless philosophical technique. Konorski then shows that it is possible to re-interpret the actual observations, which are of course incontrovertible, in terms of nerve-cell organisation. In the laying-down of conditioned reflexes, and indeed in " plastic " phenomena in general, new synaptic connections, inhibitory as well as excitatory, are supposed to be formed. Once formed, these new connections when thrown into activity become the seat of those processes of excitation and inhibition which have been the concern of students of " lower nervous activity " from Sherrington onwards. Konorski is careful to confine this approach to conditioned reflexes of the first and second types, that is to say, to the simplest manifestations of " higher nervous activity."

But to show that a consistent account can be written in neurophysiological language still falls short of proving Pavlov's contention that what he was studying was the physiology of the brain and nothing else. It is because its discussions pose problems for future experiment that this book is so important. Would physiological neuronography, for example, discover new morphological connections where stable conditioned reflexes have been built ? Work still to be done will decide whether conditioned reflexes are really directly linked with energy exchanges in the nervous system, as now seems likely, or whether we have merely discovered, in a refined way, that you cannot fool all the dogs all the time.

<div align="right">C. G. P.</div>

Advances in Enzymology and Related Subjects of Biochemistry.
Vol. IX. Edited by F. F. NORD. [Pp. x + 760, with numerous figures.] (New York and London : Interscience Publishers, Inc., 1949. 72s. net.)

THE *Advances in Enzymology* series is so firmly established in biochemical literature that no introductory remarks are needed here. The size of these volumes has been steadily increasing in recent years and it is to be hoped that the maximum size has now been reached.

A very wide range of topics is presented, from theoretical discussions of biological reactions to industrial biosynthesis. Possibly a reduction in size could have been effected with advantage by omitting the reviews on the industrial biosynthesis of fats and on the enzymic activity of frozen vegetable tissue ; the latter is concerned chiefly with the practical issues involved in food preservation. Excellent as these articles may be in themselves, they seem misplaced in a book of this kind.

The remainder of the volume gives reviews which will be invaluable in the formidable task of keeping abreast of the literature on enzymology and related subjects. It is impossible to deal individually with each of these in the space available, but a few may be mentioned.

H. E. Street gives a very readable and stimulating account of the nitrogen metabolism of higher plants. T. Mann deals with the interesting work done recently on the metabolism of semen, while the mechanism of fertilisation in metazoa is discussed in an accompanying article by J. Runnström. The review by F. Schlenk on the chemistry and enzymology of nucleic acids gives

a comprehensive account of this wide field of biochemistry. It must be pointed out, however, that his account of the enzymic synthesis of glutamine on page 497 appears to be completely erroneous.

The physico-chemical aspects of biochemistry have not been neglected ; reversible step reactions are briefly discussed by L. Michaelis and those less familiar with enzyme kinetics will be grateful for the article by A. E. Stearn ; this deals particularly with the rather neglected subject of the effect of temperature on biological reactions. The use of photochemical methods of biochemistry is fully described in an account by D. Mclaren.

It is difficult to make a general comment on a volume containing such a diversity of material. Perhaps the highest recommendation is to say that the present volume is in no way inferior to its predecessors. W. H. E.

Cold Spring Harbor Symposia on Quantitative Biology. Vol. XIII : Biological Applications of Tracer Elements. [Pp. xii + 222, with 4 plates and numerous figures.] (Cold Spring Harbor, L.I.,, N.Y. : The Biological Laboratory, 1948. $7.00.)

IT is impossible to review each of the 25 articles contained in this volume. At first sight it would appear that the subjects treated are connected only by the common technique which has been employed in their investigation ; nevertheless, certain trends in these articles are discernible. Most of them describe original researches and, while the relations of these to broader aspects of the same problem are discussed, strictly review articles are relatively few.

The quantitative treatment of results obtained in tracer studies is emphasised in the article by H. Branson, who has now developed general mathematical equations which can be applied to individual problems. Hevesy, the originator of tracer methods, gives an historical sketch of the development of tracer investigations. Apart from Hevesy's masterly historical article, the volume shows present endeavours rather than past achievements.

Researches on a wide variety of subjects are treated in this volume, but whether they relate to protein, carbohydrate, fat metabolism or other aspects of animate life, the search is always after the understanding of the fundamental reactions leading to the formation and degradation of the substances in question. It is not surprising, therefore, that most of the articles deal with questions of intermediary metabolism. Such researches naturally involve the study of the formation of the carbon-skeleton of organic compounds, and not less than 10 out of the 25 articles presented at this symposium report experiments with one of the carbon-isotopes.

Many of the fundamental biochemical reactions in unicellular organisms probably do not differ significantly from those in higher animals : the study of the former has often yielded important information about the metabolism of higher forms of life. The use of isotopes has intensified and revived such studies, a number of which are presented in this volume. In particular S. F. Carson discusses experiments as to how micro-organisms can be used as model systems to test certain fundamental types of biochemical reactions.

The study of CO_2 fixation in photosynthesis has become really amenable to experiment only since the availability of C-isotopes. Drs. Benson and Calvin present in their article experiments designed to study the path of carbon in photosynthesis.

Other problems which were discussed at this symposium are : lipid synthesis and fatty acid oxidation (K. Bernhard, K. Bloch, D. I. Crandall,

S. Gurin) ; purine metabolism (A. Bergstrand *et al.*, G. B. Brown) ; amino acid and protein metabolism (G. Ehrensvärd, D. M. Greenberg *et al.*, D. Rittenberg) ; biosynthesis of porphyrins (D. Shemin) ; cell-permeability and ion-transfer across membranes (L. B. Flexner *et al.* ; J. Sacks ; H. H. Ussing) ; the synthesis of glycogen from C-labelled intermediates as an indicator of intermediary metabolism (H. G. Wood) ; cytological effects of radiations (T. J. Arnason, R. A. Bolomy, N. H. Giles) ; CO_2 metabolism in animals and radiation hazards from ^{14}C (A. M. Brues, D. L. Buchanan) ; metabolism of Ra, Sr and Ca (W. P. Norris and W. Kisieleski) ; the use of ^{18}O in tracer studies (R. Bentley) ; phosphate metabolism of unicellular organisms (M. D. Kamen and S. Spiegelman).

The names of the authors are familiar to biologists and need no recommendation. One cannot fail to admire the works presented in this symposium. There is no doubt that the volume will be a coveted property of research workers, both as a reference and as an important document. The time is fast approaching when knowledge acquired with isotopes will not be discussed at special meetings, but will be incorporated into the general realm of science.

G. POPJÁK.

Biochemical Preparations. Vol. I. HERBERT E. CARTER, Editor-in-Chief. [Pp. xi + 76.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 20*s.* net.)

THIS book, issued under the ægis of advisory and editorial boards of distinguished American biochemists, is planned as the first of a series of volumes analogous to the well-known *Organic Syntheses*, now in its twenty-ninth year. The object is to provide authoritative, thoroughly checked methods of preparation for substances used in biochemical research, illustrating techniques and methods useful both to research workers and to advanced students. It is frankly a recipe book, but every laboratory worker will be glad to have tried and tested recipes to work from instead of having to examine critically and select from descriptions scattered through the literature.

The range is indicated by the contents : Adenosine di- and tri-phosphate ; L-alanine ; L-serine ; azobenzene-*p*-sulphonic acid trihydrate ; *p*-hydroxy-azobenzene-*p'*-sulphonic acid ; 5-nitronaphthalene-1-sulphonic acid dihydrate ; casein ; β-3:4-dihydroxyphenyl-L-alanine ; diphosphopyridine nucleotide ; α-glucose-1-phosphates ; L-glutamine ; DL-glyceraldehyde 3-phosphoric acid ; lycopene ; L-lysine monohydrochloride ; lysozyme ; D-tyrosine. The directions are full of detailed practical " tips," perhaps sometimes too specific, as when a particular brand of tomato paste is mentioned, and the American custom of referring to charcoals and filter-aids by trade marks is maintained. The writing is precise and clear, and the technical editing and production are of exemplary standard. The field to be covered by future volumes is immense ; biochemical laboratories will find the collection of this and subsequent volumes of growing value. R. K. CALLOW.

Modern Discoveries in Medical Psychology. By CLIFFORD ALLEN, M.D., M.R.C.P., D.P.M. Second edition. [Pp. xii + 236.] (London : Macmillan & Co., Ltd. 1949. 12*s.* 6*d.* net.)

THE substance of this book provided material for a course of lectures on psychological theory delivered under the auspices of the University of London, and the approach is therefore essentially pedagogic.

Each chapter is devoted to the contribution of one or more workers in the field of abnormal psychology. Mesmer, Janet, Morton Prince, Freud, Adler, Jung, Kretschmer and Pavlov are among those selected for brief life histories. The manner in which their discoveries were received is also recorded. The writer does not adhere to a particular school or discipline, but gives an impartial description of various viewpoints and theories, and makes a deliberate attempt to assess the contribution that each man has made to the field of science, confining himself to fair and unprejudiced criticism.

The structure of consciousness provides the theme of the lectures, in which theory is well and aptly illustrated by examples from everyday life and clarified by diagrammatic illustrations. Despite the abstruse subject matter, the book contains much factual material, is written in the straightforward narrative style of the experienced lecturer, and is remarkably free from psychological jargon. It is intended for undergraduate and postgraduate medical students, but is not beyond the comprehension of the intelligent layman.

To this second edition, appearing after an interval of twelve years, a chapter on physical treatments has been added, but at a time when scientific interest is centred on newer physical methods of approach it is well that attention should be directed to established principles of psychopathology. For anyone wishing to study the theory and practice of abnormal psychology in its historical setting, the book provides a valuable introduction.

MURIEL BARTON HALL.

PHILOSOPHY AND HISTORY OF SCIENCE

Gesetz, Kausalität und Wahrscheinlichkeit. By MORITZ SCHLICK. [Pp. 116.] **Grundzüge der Naturphilosophie.** By MORITZ SCHLICK. Edited by W. HOLLITSCHER and J. RAUSCHER. [Pp. x + 115.] (Vienna : Gerold & Co., 1948. $1.45 each.)

THE first of these two small volumes appears to be a reprint of the " Collected Essays " of Moritz Schlick which were published in 1938. It contains five articles, written during the decade before the last world war, on philosophical problems arising from the development of physics in this century, which are already well known to students of this subject. Schlick was one of the founders of the " Vienna Circle," in which the philosophy later known as " logical positivism " first took definite shape, and his writings are likely to make a stronger appeal to scientifically-minded readers than are the purely linguistic analyses which characterise the later work of this school. He wrote very clearly, and the study of the philosophy of science suffered a distinct loss when in 1936 he was shot dead by a mad student as he was about to deliver the final lecture of his course in the philosophy of physics at the University of Vienna.

The second volume appears not to have been published before. It is printed from notes left by Schlick on which his university lectures were based, supplemented by verbatim notes of lectures in 1927 dealing with the relation of physics to biology and other matters. Though there is nothing essentially new in the book, it is very useful to have the most mature form of Schlick's philosophy in so compact a volume. The editors are to be thanked for having made it available.

H. D.

Greek Science : Its Meaning for Us. II : Theophrastus to Galen.
By BENJAMIN FARRINGTON. Pelican Books No. A192. [Pp. 181,
with 2 figures.] (Harmondsworth : Penguin Books, Ltd., 1949.
1s. 6d. net.)

PROF. FARRINGTON here completes the survey of Greek science which, in his
earlier " Pelican " on the subject, he brought down to the death of Aristotle.
Taking up the story anew with Theophrastus, he passes from the expiring
Lyceum to Alexandria in the golden age of Euclid and Erasistratus, and so
to the Rome of Pliny and Galen. The growth of the individual sciences is
briefly traced, with illustrative extracts translated from the scientific classics
of the period. The interest of the work is enhanced by the inclusion of
topics not usually classed as scientific, such as the organisation of scholarship
and the analysis of speech and of music. Another feature is the constant
reference of developments to the social background of the period covered.

The main thesis of the book is that Greek science was a product of the
technical attack upon nature, beginning promisingly enough in the enter-
prising Pre-Socratic societies. The writer maintains that a technique of
experiment was fully established by Strato in the third century B.C., but that
its further development was paralysed through the growth of slavery.
Divorced from the manual arts, the leisured thinkers lost all touch with nature,
and all motive for industrial improvement, their philosophy becoming con-
formed to the political necessities of the slave state. The revival, at the
Renaissance, of what was at first purely Greek science, and the progress beyond
it, were conditioned, not merely by the recovery of the ancient scientific
texts, but also by the technical revolution of the Middle Ages, whereby other
sources of power were substituted for slave labour.

Whatever acceptance Prof. Farrington's philosophy of history may obtain,
he has unquestionably given us a stimulating interpretation of a process too
often treated in a superficial and conventional manner.

The name of Tannery (pp. 79, 93, 138, 180) should be printed without an
accent.

<div align="right">A. A.</div>

MISCELLANEOUS

**The Prehistory of Southern Rhodesia : An Account of the Pro-
gress of Research from 1900 to 1946.** By NEVILLE JONES.
Museum Memoir No. 2, published for the Trustees of the National
Museum of Southern Rhodesia. [Pp. 78, with 40 figures, frontispiece
and map.] (Cambridge : at the University Press, 1949. 7s. 6d. net.)

AFTER his retirement from the Museum, Mr. Neville Jones undertook this
conspectus with the primary aim of stimulating research in the Colony.
The work will also be gratefully received, however, by prehistorians generally,
especially because of its timely appearance before the meeting of the Pan-
African Congress on Prehistory to be held in South Africa in 1950.

The author begins with a detailed account of the cultural phases of the
Early Stone Age, characterised in order of date by pebble-tools of the familiar
type, and hand-axes of the South African Chellian and Acheulian types,
respectively. The Middle Stone Age is exemplified first by the rich *Bembesi*
phase, with its axes and flakes of Clactonian and Levalloisian techniques, the
successions at Bembesi and other sites being fully described. An account

follows of the succeeding proto-Still Bay, Still Bay and Magosian phases of the Upper Palæolithic which bring the Middle Stone Age to a close. Mr. Neville Jones considers that the flake industries were developed *in situ* from the earlier industries and were not to be attributed to a new invasion. The Late Stone Age is marked, as elsewhere in Africa, by the Wilton phase, with its characteristic microlithic and bone tools. The book concludes with the story of the curious hand-axes and flake tools (which include rostro-carinates) of the Ironstone Kopjes : these seem to be *sui generis*.

Throughout the work, geological evidence is fully discussed, and the author emphasises the importance of collaboration between prehistorians and geologists, paying many tributes to the latter for their help. Modesty prevented him perhaps from stressing that the benefits are mutual and that, for example, archæological research has recently led to the solution of a long-standing geological problem—that of the age of the widespread Kalahari Sand : it has now been proved to lie between the deposits of the two major wet episodes of the Early Stone Age.

In the glossary provided for the non-experts, *alluvium* is given a wide connotation (although used in the text in its accepted sense) which, one hopes, will not be adopted, but Mr. Neville Jones's use of *superposed*, instead of the now popular *superimposed*, sets a good example.

<div align="right">P. G. H. BOSWELL.</div>

Topographie. BY GENERAL DE FONTANGES. Collection Armand Colin No. 252. [Pp. 224, with 46 figures.] (Paris : Librairie Armand Colin, 1948. Frs. 150.–.)

" LA topographie," as defined by General de Fontanges in the opening words of this book, is the science of the making and use of maps. As expounded in the 219 pages that follow, it could fairly be equated with the principles and practice of topographic surveying. The " use " of maps must be understood in the sense that a conscientious reader will acquire some knowledge of the nature and limitations of the principal processes—survey, projection and cartographic drawing—that go to the making of maps and be thereby led himself to their more intelligent use. Not least he will gain a knowledge of the survey methods used in the production of the chief topographic maps of France not readily come by elsewhere.

The book is divided into two fairly equal halves. The first begins with two chapters dealing with basic definitions, measurements on maps, methods of fixing position (grids and co-ordinates), conventional signs and the representation of relief, and it may be noted in passing that azimuths are defined as angles measured from the meridian and bearings (*gisements*) as the corresponding angles measured from the *y*-axes in a grid system. A brief summary of the topographic maps of France and North Africa is included here. The remaining chapters of Part I deal with the instruments and methods that will yield useful results in surveys for particular purposes in a country where a sufficient number of reference points are available from primary survey. Part II considers the problems of primary survey itself, the accumulation of error, the nature of the framework (astronomical or geodetic), the ellipsoid of reference, the system of map projection, both the classic methods of the nineteenth century and ground and aerial photo-topographic methods receiving attention. Much ground is covered in few chapters and the General is not wrong on page 178 in thinking that the reader, daunted " par la sécheresse

presque inévitable des résumés techniques de ce genre," will not have read all the preceding paragraphs. Despite the hope he expresses in his preface, this is not an effective introduction to the subject, but a handy summary for the student of geography or surveying who already knows something about it.

D. L. L.

Oxford Junior Encyclopædia. General editors : LAURA E. SALT and GEOFFREY BOUMPHREY. **Vol. III : The Universe.** Edited by JEAN K. F. PETRIE. [Pp. xvi + 496, illustrated.] (London : Oxford University Press, 1949. 30s. net.)

THIS, the second published volume of a new encyclopædia, deals with " physical laws, astronomy, geology, weather, geography, countries and towns." The attempt to produce an up-to-date and improved Children's Encyclopædia is wholly praiseworthy, and has been thus far attended with a great measure of success. The book is of suitable size ; there are many photographs, mostly well reproduced and well selected ; the diagrams are clear and helpful ; the language is intelligible to children. The writing is, however, not always vivid or interesting enough. Some of the geographical articles show too little imagination, and are rather dull précis of text-book information. Thus the article " Germany " includes an over-elaborate division of the country into regions. A few articles adopt that form of talking down to children which describes everything as " fine " or " magnificent " and paints a falsely brilliant picture (as, for example, " Newfoundland "). The article " England," while avoiding these faults, fall into some needless errors ; e.g. Scafell and Skiddaw are not " granite hills " (p. 155), and Suffolk does not extend into the Fens (p. 157).

These criticisms of detail do not apply to the bulk of the book, but more important complaints may be made of the allocation of space within the volume. It has clearly not been written for the United States market. The British Isles are given about 11 pages, the United States only 4. Washington and Winchester get the same amount of space, and New York has barely more than York.

More serious perhaps is the conflict between subjects. Geography, geology and astronomy seem to be well catered for, but the natural expectation that a large proportion would be devoted to physics and chemistry is not fulfilled. Chemistry, indeed, seems to have been reduced to the two-page article " Chemistry " and little else. There are no entries under Acid or Alkali, Element, Carbon or most of the important elements. It is to be hoped that this deficiency may be remedied in the still unpublished volumes, but it is difficult from the sub-titles to guess which.

A. F. M.

The Wealth of India. A Dictionary of Indian Raw Materials and Industrial Products. Vol. I in two parts : **Raw Materials** [pp. xxviii + 254, with 39 plates] and **Industrial Products** [pp. xii + 182, with 8 plates and a number of other illustrations.] (New Delhi : The Indian Council of Scientific and Industrial Research, 1948. 24s. and 12s. Insurance and postage, 8s.)

FOR many years the *Dictionary of Economic Products of India,* compiled by the late Sir George Watt between fifty and sixty years ago, and the abridged version under the title of the *Commerical Products of India* which he com-

pleted ten years later, have been the standard works of reference on the products and economic resources of the Indian sub-continent.

With lapse of time and the ever-quickening tempo of development and change they have, however, inevitably become to an extent outmoded and out of date. On this account, in 1942 the Indian Council of Scientific and Industrial Research decided to undertake the formidable task of preparing a revised version, which would incorporate the accumulated experience of recent years and present a complete picture of the position as it is to-day.

An Advisory Council and an Editorial Committee were set up, the latter under the chairmanship of Dr. S. S. Bhatnagar, F.R.S., and Dr. B. L. Manjanuth was appointed Editor-in-Chief, with seven sectional sub-committees dealing with different aspects and a staff of some thirteen sub-editors and technical assistants.

It was decided that the work should include all economic products and raw materials of India, and that it should be alphabetically arranged on the basis of scientific nomenclature. The articles were to be based upon published material, and would be concise and fully documented ; historical, descriptive and purely scientific sections would be made as brief as possible ; while all statistics should be critically examined before acceptance. The title chosen was the *Wealth of India*, and the completed work would consist of six volumes, each consisting of two parts, one dealing with raw materials and the other with industrial products.

The first volume has now been published ; it deals with subjects falling under the initials A–B. It is prefaced by a foreword from Pandit Jawaherlal Nehru.

The encyclopædic form of treatment within the limits prescribed must presumably to some extent restrict the scope of the work, since it is hard to see how it can permit, for example, any account of land policy, land management, conservation of resources or the broader aspects of economics, all of which profoundly affect the production and utilisation of materials. On the other hand, it has the manifest advantage that it facilitates reference to information on any product.

So far as the first part of the first volume, dealing with raw materials, is concerned, let us say at once that the authors and editors have accomplished their task with considerable success. The great majority of the articles are models of concise and authoritative statement, references to original literature have been abundantly provided, and there is a welcome absence of the excessive detail which appeared in some of the articles in the original work.

Many of the longer articles are of a high level of excellence ; in particular those on Arachis, Areca, Bambusa, Borassus and Brassica struck the present reviewer as specially good. As a minor point it seemed a pity that the article on Arachis contains no discussion of the possibility of mechanical methods of handling the crop under Indian conditions.

The standard of production of this part is also commendably high ; paper and typography are above reproach, while the numerous plates, some of which are in colour, are admirable both in choice of subject and manner of reproduction ; a minor blemish is that they do not always face the page which they are intended to illustrate.

The second part of the volume, dealing with industrial production, although not without merit, hardly reaches the high standard set by its companion. Industrial development in India on a large scale is comparatively recent, but, although it is possible to ascertain from the volume the present

position in regard to a number of industries and products, much space is taken up with descriptions of standard modern industrial practices, details of which could be obtained from text-books. On the other hand, details concerning indigenous manufacturing methods are somewhat scanty.

Like the companion volume this part contains a number of excellent plates, but the typography and general presentation fall somewhat short of the high standard set in these respects. From the standpoint of uniformity it seems unfortunate also that it should be printed on paper of a different quality and of a different shade.

Taken together however the two parts of Vol. I represent a notable achievement, and if the succeeding volumes maintain this level the work should achieve the objects of those responsible for its conception, namely to provide a standard work of reference on the economic resources of India.

It is no reflection on the band of workers who have combined to produce it to sound in retrospect a note of admiration and respect for the erudition and industry of George Watt, who over fifty years ago compiled, almost single-handed, the original dictionary from which the present work takes its roots. When it achieves completion it should rank as a tribute to his memory as well as a monument to the work of those who have compiled it.

H. TEMPANY.

Basic Naval Architecture. By K. C. BARNABY, O.B.E., B.Sc. [Pp. 339 with 100 figures.] (London : Hutchinson's Scientific and Technical Publications, 1949. 42s. net.)

THIS is a book for the practitioner rather than for the student. The latter will probably find it fairly heavy going: There is a scarcity of the diagrams which would illustrate some of the more complicated matters in the consideration of stability and trim. Moreover, there appears to be something at fault with the sequence in which subjects are treated ; the sections are numbered, but there are too many references to numbers of sections which have not been reached instead of to sections which have been passed and can be used as reminders. This may be a consequence of the treatment not being sufficiently " basic." The practitioner who is moderately conversant with the theoretical basis of his work will not be concerned with such defects, and he will find useful information scattered throughout the book, especially if he is concerned with small craft. There is not much guidance for the practitioner who deals with cargo tramps, or the larger types of ship ; Mr. Barnaby's experience lies in other fields. That limitation is indicated by the fact that the very important business of estimating hull weights is treated in 25 lines, supplemented by 15 values of the coefficients for weights of hull and net steel in relation to the cubic number. There is no indication of the principle which should be applied in all estimates of weights for ships. The principle is that, since there must be a considerable amount of guessing, it is better to guess a large number of small weights rather than a small number of large weights ; by the adoption of the former course the chances of the errors balancing are increased. The problem of launching is treated more fully than in earlier works on naval architecture. But Mr. Barnaby is rather behind the times in his retention of the practice of sliding a profile drawing of the ship down a drawing of the ways ; it is a simple matter to determine the draughts at successive positions by arithmetical means. A reference has been made

above to the practitioner who is moderately conversant with the theoretical basis of his work. The qualification was made because the practitioner who is fully conversant will find several lapses throughout the book ; wherefore the original indication that the book is not quite one for the student.

A. M. R.

Science in Education. By M. C. NOKES, M.C., M.A., B.Sc. [Pp. xii + 158.] (London : Macdonald & Co. (Publishers), Ltd., 1949. 8s. 6d. net.)

THIS book lacks cohesion and there is little sense of direction in the main argument. There is a straightforward account of what science is (limited rather severely to physical science), lucidly presented and well illustrated. Unfortunately the philosophical side of the subject is rather muddled. All might have been well if the author had not chosen to bring in an account of Ogden and Richards' analysis of language as a tedious means of deciding what scientists mean by " truth." One wonders at the procedure, but presumably the author wished to avoid so far as possible metaphysical problems about " reality " or " existence." All the same, his discussion of symbolic fictions in science, and of laws and theories, is not really satisfying.

In the discussion of education one hoped to find a (much-needed) critical examination of just what our science teaching is really achieving. The author seems to suppose that all is well here and treats us to the pomposities of Jung's classification of mental types in an argument of highly dubious validity. This is the most disappointing part of the book. Such a statement about the history of art as : " there have been occasions when a confluence of human personality towards the introvert sensation type has taken place " (p. 151) is really very difficult to understand.

A. E. B.

Russian Science Readings (Chemistry, Physics, Biology). By L. LIGHT, Ph.D., A.R.I.C. [Pp. 98.] (London and Philadelphia : Hirschfeld Bros., Ltd., 1949. 7s. 6d. net.)

SINCE the War, and especially since the end of 1947, when Soviet scientific journals ceased publication in English, Russian has become the second scientific language, if still a poorer second than German was before the War. London University has recognised the change, graduation in Physics and Chemistry being conditional on passing in two languages, of which Russian may now be one. But the problem of teaching Russian to science students has scarcely yet been tackled. Scientists are said, rightly, I believe, to prefer the " moment de la quantité de mouvement " to the " plume de ma tante " school of language teaching, but few teachers of Russian can meet this requirement. If this difficulty can be overcome, there remains that of finding texts in sufficient number for a class. The need, then, could scarcely be greater for a reader " that would smooth the path of those wishing to study Russian scientific literature in the original," which is the declared aim of the book under review.

About one third of the book is occupied by texts, which are accented, the bulk of the remainder being notes and vocabulary, both excellent ; an especially clear and agreeable type face has been used, and misprints appear to be both few and trivial. Unhappily, however, the texts, which have been taken from Russian school books, are, especially in Physics, almost grotesquely

elementary. It is surprising that an author with experience in teaching scientists a foreign language should have made the mistake of offering them material unsuitable for students over 14 years of age. The tragedy is all the greater since much care has been devoted to the preparation of the book, the standard of linguistic difficulty is adequate and it is the only book of its kind published in this country. One can only hope that, the need being so great, a more suitable second edition may soon be available.

<div align="right">J. C. E. JENNINGS.</div>

A Century of Book Publishing, 1848–1948. [Pp. viii + 74, with 12 plates.] (New York, Toronto, London : D. Van Nostrand Company, Inc., 1948.)

THE history of a Publishing Firm is always interesting, especially when, as in this instance, it is written round those who have had the control of it. The personality of the founder, David Van Nostrand, obviously settled the lines along which the firm has developed. The spacious days of publishing have long passed, but the maintenance of personal contact between author and publisher is, as it should be, still continued in the firm of Van Nostrand. The story of how the various types of books came to be included in the Company's range of publications makes interesting reading. The reputation of the firm through its hundred years of existence can well be understood when one reads of the prominent scientists and technicians who have published under the Van Nostrand imprint. The present President, Edward M. Crane, is known far beyond his native land, and we wish the firm continued success in catering for the needs of the academic and industrial worker.

<div align="right">F. P. D.</div>

Science News, 13. Edited by J. L. CRAMMER. [Pp. 162, with 2 coloured plates, 9 other plates and 26 figures.] (Harmondsworth : Penguin Books, Ltd., 1949. 1s. 6d. net.)

THIS slim volume must contain something to make it worth its price for almost every thinking adult, and many will read with absorbed interest its widely ranging and mostly pleasingly written essays from cover to cover. Facts from specialised fields like chromatography, chloromycetin, and the problem of cancer, and more general essays such as those on the sources of solar radiation and on experimental embryology, so delightfully informative for the layman or the scientist whose way does not lie in these particular fields, are represented here. Still other articles which might not at first seem to be " science " will prove astonishing revelations for many ; thus one learns not only the utterly amazing facts of India's population, but also, for example, that 124,000,000 peas are photoelectrically individually inspected each day by a single firm so that no blemished ones may be canned. This is a most informative booklet which, however, most deserves to be read for the sheer enjoyment which it can give.

<div align="right">A. H. COOK.</div>

BOOKS RECEIVED

Introduction to Algebraic Geometry. By J. G. Semple and L. Roth. Oxford : at the Clarendon Press, 1949. (Pp. xvi + 446, with 16 figures and 6 tables.) 30s. net.

University Mathematics. A Textbook for Students of Science and Engineering. By Joseph Blakey, Ph.D., Senior Lecturer in Mathematics, Constantine Technical College, Middlesbrough. London and Glasgow : Blackie & Son, Ltd., 1949. (Pp. viii + 527.) 25s. net.

Living Mathematics. By Ralph S. Underwood and Fred W. Sparks, Professors of Mathematics, Texas Technological College. Second edition. New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. (Pp. x + 374, with 88 figures and 8 tables.) 36s. net.

The Structure of the Universe. An Introduction to Cosmology. By G. J. Whitrow, M.A., D.Phil. (Oxon.), F.R.A.S., Lecturer in Mathematics at the Imperial College of Science and Technology. Hutchinson's University Library. London : Hutchinson's Scientific and Technical Publications, 1949. (Pp. 171.) 7s. 6d. net.

Annual Report of the Director of the Meteorological Office for the year April 1, 1948 to March 31, 1949. London : H.M. Stationery Office, 1949. (Pp. 48.) 9d. net.

Oscillations of the Earth's Atmosphere. By M. V. Wilkes, Director of the University Mathematical Laboratory, Cambridge. Cambridge Monographs on Physics. Cambridge : at the University Press, 1949. (Pp. x + 76, with 23 figures and 8 tables.) 12s. 6d. net.

Meteorology of Airfields. By C. S. Durst, B.A. M.O. 507. London : H.M. Stationery Office, 1949. (Pp. 87, with 30 figures and 42 tables.) 2s. net.

Atmospheric Turbulence. By O. G. Sutton, B.Sc. (Wales), B.Sc. (Oxon.), Bashforth Professor of Mathematical Physics at the Military College of Science, Shrivenham. Methuen's Monographs on Physical Subjects. London : Methuen & Co., Ltd., 1949. (Pp. viii + 107, with 4 figures.) 6s. net.

Cosmic Radiation. Colston Papers based on a Symposium promoted by the Colston Research Society and the University of Bristol in September 1948, now published as a Special Supplement to *Research, a Journal of Science and its Applications*. London : Butterworth's Scientific Publications, 1949. (Pp. viii + 189, with numerous figures.) 25s. net.

Some Recent Researches in Solar Physics. By F. Hoyle, M.A., Fellow of St. John's College, Cambridge. Cambridge Monographs on Physics. Cambridge : at the University Press, 1949. (Pp. xii + 134, with 8 figures and 35 tables.) 12s. 6d. net.

A University Text-Book of Physics. Vol. II : Sound. By J. H. Poynting and Sir J. J. Thomson. Revised by W. S. Tucker, O.B.E., D.Sc.,

M.R.I. Tenth edition. London : Charles Griffin & Co., Ltd., 1949. (Pp. viii + 251, with 121 figures and 8 tables.) 20s. net.

A Textbook on Heat. By J. H. Awbery, M.A., B.Sc., F.Inst.P. London, New York, Toronto : Longmans, Green & Co., 1949. (Pp. x + 302, with 50 figures.) 15s. net.

Heat. A Textbook for Higher Certificate and Intermediate Students. By M. Nelkon, M.Sc. (Lond.), A.K.C., William Ellis School, London. London and Glasgow : Blackie & Son, Ltd., 1949. (Pp. viii + 240, with 89 figures.) 9s. net.

Surface Tension and the Spreading of Liquids. By R. S. Burdon, D.Sc., F.Inst.P., Reader in Physics, University of Adelaide. Second edition. Cambridge Monographs on Physics. Cambridge : at the University Press, 1949. (Pp. xiv + 92, with 22 figures, including 3 plates.) 12s. 6d. net.

Luminescent Materials. By G. F. J. Garlick, University of Birmingham. Monographs on the Physics and Chemistry of Materials. Oxford : at the Clarendon Press, 1949. (Pp. viii + 254, with 127 figures.) 21s. net.

Practical Spectroscopy. By C. Candler, M.A., F.Inst.P. London : Hilger & Watts, Ltd., 1949. (Pp. viii + 190, with 4 plates and 113 figures.) 21s. net.

An Introduction to Molecular Spectra. By Raynor C. Johnson, M.A. (Oxon.), D.Sc. (Lond.), Master of Queen's College, University of Melbourne. London : Methuen & Co., Ltd., 1949. (Pp. xiv + 296, with 8 plates and 151 figures.) 40s. net.

Ions, Electrons, and Ionizing Radiations. By James Arnold Crowther, Sc.D., F.Inst.P., Emeritus Professor of Physics in the University of Reading. Eighth edition. London : Edward Arnold & Co., 1949. (Pp. x + 322, with 125 figures, including ·7 plates, and 17 tables.) 21s. net.

Introduction to Atomic Physics. By S. Tolansky, Ph.D., D.I.C., D.Sc., Professor of Physics, Royal Holloway College, London University. With a Foreword by Sir Lawrence Bragg, F.R.S. Third edition. London, New York, Toronto : Longmans, Green & Co., 1949. (Pp. xii + 371, with 5 plates, 115 figures and 11 tables.) 15s. net.

Theory of Atomic Nucleus and Nuclear Energy-Sources. By G. Gamow, Professor of Theoretical Physics, George Washington University, and C. L. Critchfield, Associate Professor of Physics, University of Minnesota. Being the third edition of "Structure of Atomic Nucleus and Nuclear Transformations." International Series of Monographs on Physics. Oxford : at the Clarendon Press, 1949. (Pp. viii + 344, with 5 plates, 62 figures and 27 tables.) 30s. net.

Radioactive Measurements with Nuclear Emulsions. By Herman Yagoda, Senior Physical Chemist, National Institute of Health. New York : John Wiley & Sons, Inc.; London : Chapman & Hall, Ltd., 1949. (Pp. x + 356, with 75 figures and 31 tables.) 40s. net.

Excited States of Nuclei. By S. Devons, Ph.D., Fellow of Trinity College, Cambridge. Cambridge Monographs on Physics. Cambridge : at the University Press, 1949. (Pp. x + 152, with 27 figures and 6 tables.) 12s. 6d. net.

The Theory of Atomic Collisions. By N. F. Mott and H. S. W. Massey. Second edition. The International Series of Monographs on Physics. Oxford : at the Clarendon Press, 1949. (Pp. xii + 388, with 69 figures.) 35s. net.

Handbook of Industrial Radiology. By Members of the Industrial Radiology Group of the Institute of Physics. Edited by J. A. Crowther, M.A., Sc.D., F.Inst.P. Second edition. London: Edward Arnold & Co., 1949. (Pp. viii + 218, with 106 figures and 9 tables.) 21s. net.

A Second Course of Electricity. By A. E. E. McKenzie, M.A., Trinity College, Cambridge. Cambridge: at the University Press, 1949. (Pp. viii + 357, with 327 figures and 14 portraits.) 12s. 6d.

Radio Engineering. Vol. II. By E. K. Sandeman, Ph.D., B.Sc., A.C.G.I., M.I.E.E., Ministry of Supply. London: Chapman & Hall, Ltd., 1949. (Pp. xxii + 579, with 192 figures.) 40s. net.

Industrial High Frequency Electric Power. By E. May, B.Sc., A.C.G.I., M.I.E.E., Chief Electrical Engineer, Birlec Ltd. London: Chapman & Hall, Ltd., 1949. (Pp. xii + 355, with 208 figures.) 32s. net.

Aerials for Metre and Decimetre Wave-Lengths. By R. A. Smith, M.A., Ph.D., A.M.I.E.E., Superintendent, Physics Department, Telecommunications Research Establishment, Ministry of Supply. Cambridge: at the University Press, 1949. (Pp. xii + 218, with 125 figures, including 3 plates, and 15 tables.) 18s. net.

Laboratory and Workshop Notes. A Selection reprinted from the *Journal of Scientific Instruments*. Compiled and edited by Ruth Lang, Ph.D., A.Inst.P., for the Institute of Physics. London: Edward Arnold & Co., 1949. (Pp. xii + 272, with 195 figures.) 21s. net.

Tables Azéotropiques. Vol. I: Azéotropes binaires orthobares. By Maurice Lecat, Docteur ès sciences naturelles, physiques et mathématiques, Ingénieur civil des Mines. Second edition. Published by the Author, 1949. (Pp. xvi + 396.) Belgian Frs. 1000.–.

Elements of Mechanical Vibration. By C. R. Freberg, Head, Engineering Research Division, Southern Research Institute, and E. N. Kemler, Research Professor of Mechanical Engineering, College of Engineering, New York University. Second edition. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1949. (Pp. xiv + 227, with 179 figures and 18 tables.) 30s. net.

Engineering Laminates. Edited by Albert G. H. Dietz, Sc.D., Associate Professor, Department of Building Engineering and Construction, Massachusetts Institute of Technology. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1949. (Pp. viii + 797, with 331 figures and 156 tables.) 80s. net.

Progress in Metal Physics, 1. Editor, Bruce Chalmers, D.Sc., Ph.D. London: Butterworth's Scientific Publications, 1949. (Pp. viii + 401, with 15 plates, 134 figures and 26 tables.) 45s. net.

Deformation and Flow. An Elementary Introduction to Theoretical Rheology. By Markus Reiner, Dr.Techn., Professor at the Technical College, Haifa. London: H. K. Lewis & Co., Ltd., 1949. (Pp. xx + 346, with 95 figures, including 2 plates.) 32s. 6d. net.

Industrial Rheology and Rheological Structures. By the late Henry Green. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1949. (Pp. xii + 311, with 78 figures and 11 tables.) 58s. net.

An Advanced Treatise on Physical Chemistry. Vol. I. By J. R. Partington, M.B.E., D.Sc., Professor of Chemistry in the University of London (Queen Mary College). London, New York, Toronto: Longmans, Green & Co., 1949. (Pp. xlii + 943, with 269 figures.) 80s. net.

Colloid Science. Edited by H. R. Kruyt, formerly Professor of Physica Chemistry, Utrecht University. Vol. II: Reversible Systems. Amster-

dam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. (Pp. xx + 753, with numerous figures and tables.) 90s. net.

A Textbook of Colloid Chemistry. By Harry Boyer Weiser, Professor of Chemistry at The Rice Institute. Second edition. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. x + 444, with 117 figures and 73 tables.) 44s. net.

Surface Chemistry. Papers presented for a Discussion at a joint meeting of the Société de Chimie Physique and the Faraday Society held at Bordeaux from 5 to 9 October 1947 in honour of Prof. Henri Devaux, published as a Special Supplement to *Research*. London : Butterworth's Scientific Publications, 1949. (Pp. viii + 334, with 13 plates and numerous figures and tables.) 25s. net.

The Colloid Chemistry of the Silicate Minerals. By C. Edmund Marshall, Professor of Soils, University of Missouri. Vol. I of the Agronomy series. New York : Academic Press, Inc. ; London : H. K. Lewis & Co., Ltd., 1949. (Pp. x + 195, with 85 figures and 20 tables.) 43s. net.

Ion Exchange. Theory and Application. Edited by Frederick C. Nachod, Sterling-Winthrop Research Institute, Rensselaer, New York. New York : Academic Press, Inc. ; London : H. K. Lewis & Co., Ltd., 1949. (Pp. xii + 411, with 124 figures and 49 tables.) 64s. net.

The Adsorption of Gases on Solids. By A. R. Miller, Imperial Chemical Industries Research Fellow at the Royal Society Mond Laboratory, Cavendish Laboratory, Cambridge. Cambridge Monographs on Physics. Cambridge : at the University Press, 1949. (Pp. x + 133, with 38 figures and 8 tables.) 12s. 6d. net.

Physical Methods of Organic Chemistry, Part I. Edited by Arnold Weissberger. Second edition. Technique of Organic Chemistry, Vol. I. New York and London : Interscience Publishers, Inc., 1949. (Pp. xii + 1072, with 355 figures.) 100s. net.

Molecules and Crystals in Inorganic Chemistry. By A. E. van Arkel, University of Leiden. Translated by J. C. Swallow. London : Butterworth's Scientific Publications, 1949. (Pp. x + 234, with 45 figures and 34 tables.) 17s. 6d. net.

Chemical Constitution and Properties of Engineering Materials. By P. C. Carman, M.Sc. (N.Z.), Ph.D. (Lond.), Principal Research Officer, National Chemical Laboratory, Pretoria. London : Edward Arnold & Co., 1949. (Pp. xii + 894, with 236 figures and 130 tables.) 50s. net.

A Chemistry of Plastics and High Polymers. By Patrick D. Ritchie, B.Sc., Ph.D., F.R.I.C., Head of the Department of Chemistry, Central Technical College, Birmingham. London : Cleaver-Hume Press, Ltd., 1949. (Pp. viii + 288, with 34 figures.) 25s. net.

The Physics of Rubber Elasticity. By L. R. G. Treloar, British Rubber Producers' Research Association. Monographs on the Physics and Chemistry of Materials. Oxford : at the Clarendon Press, 1949. (Pp. viii + 255, with frontispiece and 114 figures.) 21s. net.

Fundamentals of Synthetic Polymer Technology in its Chemical and Physical Aspects. By R. Houwink, External Lecturer in the Technical University at Delft. Second edition. Elsevier's Polymer Series. Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. (Pp. xii + 258, with 194 figures and 67 tables.) 28s. net.

Glass and Glass Manufacture. By Percival Marson, Consultant upon Refractory Materials. Fourth edition, revised and enlarged by L. M. Angus-Butterworth, M.A., M.I.Mech.E., F.R.G.S., F.S.A.Scot., Fellow of the

Society of Glass Technology. Common Commodities and Industries Series. London : Sir Isaac Pitman & Sons, Ltd., 1949. (Pp. x + 145, with frontispiece and 42 figures.) 8s. 6d. net.

A Bibliography of Dyeing and Textile Printing. Comprising a list of books from the sixteenth century to the present time (1946). By L. G. Lawrie, A.R.I.C. London : Chapman & Hall, Ltd., 1949. (Pp. 143.) 15s. net.

Chemical Laboratory Experiments. By George W. Watt, Professor of Chemistry, and Lewis F. Hatch, Associate Professor of Chemistry, the University of Texas. New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. (Pp. x + 185, looseleaf, with 35 figures.) 17s. net.

A New Dictionary of Chemistry. Edited by Stephen Miall, LL.D., B.Sc., and L. Mackenzie Miall, B.A., F.R.I.C. Second edition. London, New York, Toronto : Longmans, Green & Co., 1949. (Pp. x + 589.) 60s. net.

Alcohol. A Fuel for Internal Combustion Engines. By S. J. W. Pleeth, B.Sc., F.Inst.Pet., Chief Chemist, Cleveland Petroleum Co., Ltd. London : Chapman & Hall, Ltd., 1949. (Pp. xvi + 259, with 61 figures, including 2 plates, and 43 tables.) 28s. net.

Chemistry of Specific, Selective and Sensitive Reactions. By Fritz Feigl, Eng., Dr.Sc., Laboratory of Mineral Products, Ministry of Agriculture, Rio de Janeiro. Translated by Ralph E. Oesper. New York : Academic Press, Inc. ; London : H. K. Lewis & Co., Ltd., 1949. (Pp. xiv + 740, with 29 tables.) 97s. 6d. net.

Modern Methods for the Analysis of Aluminium Alloys. By a Committee of Chemists convened by ALAR. London : Chapman & Hall, Ltd., 1949. (Pp. viii + 144, with 11 figures.) 13s. 6d. net.

Metallurgy for Engineers. By E. C. Rollason, M.Sc., Ph.D., F.I.M., Delegate Director and Research Manager, Murex Welding Processes, Ltd. Second edition. London : Edward Arnold & Co., 1949. (Pp. viii + 339, with 179 figures and 63 tables.) 16s. net.

Metallic Creep and Creep Resistant Alloys. By A. H. Sully, M.Sc., Ph.D. London : Butterworth's Scientific Publications, 1949. (Pp. xii + 278, with 138 figures, including 16 plates, and 33 tables.) 25s. net.

The Ferrous Metal Industry in Germany during the period 1939–1945. By Geo. Patchin and Ernest Brewin. B.I.O.S. Overall Report No. 15. London : H.M. Stationery Office, for the British Intelligence Objectives Sub-Committee, 1949. (Pp. 270.) 4s. 6d. net.

Metals Reference Book. Edited by Colin J. Smithells, M.C., D.Sc., F.I.M., Director of Research, British Aluminium Co., Ltd. London : Butterworth's Scientific Publications, 1949. (Pp. xvi + 735, with numerous figures and tables.) 60s. net.

A Student's Introduction to Geology, mainly Physical. By George Macdonald Davies. London : Thomas Murby & Co., 1949. (Pp. viii + 246, with 175 figures.) 18s. net.

Historical Geology. By Carl O. Dunbar, Professor of Paleontology and Stratigraphy in Yale University. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. xii + 567, with frontispiece and 350 figures.) 40s. net.

The Middle Silurian Rocks of North Wales. By P. G. H. Boswell, A.R.C.S., D.Sc., F.R.S., Emeritus Professor of Geology in the Imperial College of Science and Technology. London : Edward Arnold & Co., 1949. (Pp. xvi + 448, with 25 plates and 107 text figures and folders.) 80s. net.

The Living Plant and the Science of Physical and Ethereal Spaces. A Study of the "Metamorphosis of Plants" in the Light of Modern Geometry and Morphology. Clent, Stourbridge, Worcs. : Goethean Science Foundation, 1949. (Pp. 77.) 8*s.* 6*d.* net.

Introgressive Hybridization. By Edgar Anderson, Geneticist, Missouri Botanical Garden, Engelmann Professor of Botany, Washington University, St. Louis. Biological Research Series. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. x + 109, with 23 figures.) 24*s.* net.

Natural History of the Danish Lichens. By Olaf Galløe, Ph.D. Parts I-VII. Copenhagen : Einar Munksgaard, 1927-1948. (Part I : pp. 93, with 388 figures in 160 plates ; Part II : pp. 84, with 416 figures in 128 plates ; Part III : pp. 114, with 345 figures in 127 plates ; Part IV : pp. 81, with 559 figures in 133 plates ; Part V : pp. 117 with 728 figures in 140 plates ; Part VI : pp. 103, with 541 figures in 88 plates ; Part VII : pp. 62, with 657 figures in 101 plates.) Dan. Kr. 40.- per part.

Fungi and Plant Disease. By B. B. Mundkur, M.A., Ph.D., F.N.I., Division of Plant Diseases, Directorate of Plant Protection and Quarantines, Ministry of Agriculture, New Delhi. London : Macmillan & Co., Ltd., 1949. (Pp. x + 246, with 130 figures.) 16*s.* net.

Fiches d'Identification du Zooplancton. Publiées sous la direction de Dr. P. Jespersen et F. S. Russell. Conseil Permanent International pour l'Exploration de la Mer. Copenhagen : Andr. Fred. Høst & Sons, 1949. (Sheets 1-17.) Kr. 10.00.

The Classification of Animals. An Introduction to Zoological Taxonomy. By W. T. Calman, C.B., D.Sc., LL.D., F.R.S., formerly Keeper of Zoology, British Museum (Natural History). Methuen's Monographs on Biological Subjects. London : Methuen & Co., Ltd., 1949. (Pp. viii + 54.) 4*s.* 6*d.* net.

Comparative Anatomy. An Introduction to the Vertebrates. By Leverett A. Adams, University of Illinois, and Samuel Eddy, University of Minnesota. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. viii + 520, with 364 figures.) 40*s.* net.

On Indian Insect Types. Edited by Dr. M. B. Mirza, Professor of Zoology. I : External and Internal Anatomy of the Buffalo-Louse, *Hœmatopinus tuberculatus* Burmeister. By M. A. H. Qadri, M.Sc., Ph.D. (Alig.), Ph.D. (Cantab.), F.R.E.S., F.Z.S. (London). Aligarh Muslim University Publications. (Pp. 21, with 9 plates.) Rs. 3.-.

The Philosophy and Practice of Bee-Keeping. By A. L. Gregg, M.A., M.D., M.Ch., Past President, British Bee-Keepers' Association and Middlesex County B.K.A. Bee Craft, Ltd., "Bracken Dene," Manor Way, Petts Wood, Kent, 1949. (Pp. 240, with frontispiece and 28 figures, including 10 plates.) 12*s.* 6*d.* net.

Farm Work Simplification. By Lawrence M. Vaughan, Ph.D., Extension Economist, Division of Agricultural Economics, Extension Service, U.S.D.A., and Lowell S. Hardin, Ph.D., Associate Professor of Agricultural Economics, Purdue University. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. xii + 145, with 49 figures.) 23*s.* net.

What is Man ? Evolution's Answer. By Alfred Machin. London : C. A. Watts & Co., Ltd., 1949. (Pp. vi + 209.) 10*s.* 6*d.* net.

Advances in Enzymology and Related Subjects of Biochemistry, Vol. IX. Edited by F. F. Nord, Fordham University, New York. New York

and London : Interscience Publishers, Inc., 1949. (Pp. x + 760, with numerous figures and tables.) 72*s.* net.

A Symposium on the Use of Isotopes in Biology and Medicine. Madison : The University of Wisconsin Press, 1948. (Pp. xiv + 445, with 11 plates and numerous figures and tables.) $5.00.

Pharmacology and Toxicology of Uranium Compounds. With a Section on the Pharmacology and Toxicology of Fluorine and Hydrogen Fluoride. Edited by Carl Voegtlin, Ph.D., formerly Chief of the Division of Pharmacology, National Institute of Health, U.S. Public Health Service, and Harold C. Hodge, Ph.D., Professor of Pharmacology and Toxicology, School of Medicine and Dentistry, University of Rochester. National Nuclear Energy Series, Division VI, Vol. I (in two parts). New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. (Pp. xviii + 1084, with 375 figures, including 13 coloured plates, and 304 tables.) 85*s.* net.

Industrial Hygiene and Toxicology. Vol. II. Edited by Frank A. Patty. New York and London : Interscience Publishers, Inc., 1949. (Pp. xxviii, 533–1138, with 7 figures and 166 tables.) 120*s.* net.

Sexual Behaviour, Normal and Abnormal. By Dr. Eustace Chesser. London : Medical Publications, Ltd., 1949. (Pp. x + 220.) 21*s.* net.

The Human Body and its Functions : An Elementary Textbook of Physiology. By C. H. Best, C.B.E., M.A., M.D., D.Sc., F.R.S., F.R.C.P. (Canada), Professor and Head of Department of Physiology, and N. B. Taylor, V.D., M.D., F.R.S. (Canada), M.R.C.S. (Eng.), L.R.C.P. (Lond.), F.R.C.S. (Edin.), F.R.C.P. (Canada), Professor of Physiology, University of Toronto. Second edition. London : Chapman & Hall, Ltd. ; New York : Henry Holt & Co., Inc., 1949. (Pp. xii + 500, with 8 coloured plates and 363 figures.) 18*s.* net.

Modern Discoveries in Medical Psychology. By Clifford Allen, M.D., M.R.C.P., D.P.M., Physician in charge of the Psychiatric Department of the Seamen's Hospital, Greenwich. Second edition. London : Macmillan & Co., Ltd., 1949. (Pp. xii + 236.) 12*s.* 6*d.* net.

Sir Arthur Eddington, Man of Science and Mystic. By L. P. Jacks. The Second Arthur Stanley Eddington Memorial Lecture, 2 November 1948. Cambridge : at the University Press, 1949. (Pp. 33.) 2*s.* net.

Hopkins and Biochemistry, 1861–1947. Papers concerning Sir Frederick Gowland Hopkins, O.M., P.R.S., with a Selection of his Addresses and a Bibliography of his Publications. Edited by Joseph Needham, F.R.S., Sir William Dunn Reader in Biochemistry, and Ernest Baldwin, Ph.D., University Lecturer in Biochemistry, Cambridge. With a Foreword by A. C. Chibnall, F.R.S., Sir William Dunn Professor of Biochemistry. A Commemoration Volume prepared on the Occasion of the First International Congress of Biochemistry, Cambridge, 1949. Cambridge : W. Heffer & Sons, Ltd., 1949. (Pp. x + 361, with 11 plates and 1 other illustration.) 18*s.* net.

George Ellett Coghill, Naturalist and Philosopher. By C. Judson Herrick. U.S.A. : University of Chicago Press ; Great Britain and Ireland : Cambridge University Press, 1949. (Pp. xii + 280, with frontispiece.) 40*s.* net.

Faraday's Discovery of Electro-Magnetic Induction. By Thomas Martin, M.Sc., F.Inst.P. London : Edward Arnold & Co., 1949. (Pp. 160, with 4 plates and 55 figures.) 9*s.* net.

The Origins of Modern Science 1300–1800. By H. Butterfield, M.A., Professor of Modern History in the University of Cambridge. London : G. Bell & Sons, Ltd., 1949. (Pp. x + 217.) 10*s.* 6*d.* net.

A New Survey of Science. A revised and enlarged edition of "Science Marches On." By Walter Shepherd. London : George Harrap & Co., Ltd., 1949. (Pp. 510, with 35 plates and 221 figures.) 15*s.* net.

Freedom from Want. A Survey of the Possibilities of Meeting the World's Food Needs. A Symposium edited by E. E. DeTurk, Ph.D., for the American Association for the Advancement of Science. With a foreword by Norris E. Dodd, Director-General, Food and Agriculture Organization of the United Nations. Waltham, Mass. : The Chronica Botanica Co. ; London : Wm. Dawson & Sons, Ltd., 1949. (*Chronica Botanica*, Vol. XI, No. 4, pp. 207–284, with frontispiece and other illustrations.) 16*s.* net.

Le Rameau vivant du Monde. Vol. III : Perspectives nouvelles du Monde animé. By Georges Matisse. Bibliothèque de Philosophie contemporaine, Logique et Philosophie des Sciences. Paris : Presses Universitaires de France, 1949. (Pp. iv + 292, with 9 figures.) Frs. 600.–.

The Power and Limits of Science. A Philosophical Study. By E. F. Caldin, M.A., Lecturer in Chemistry in the University of Leeds. London : Chapman & Hall, Ltd., 1949. (Pp. x + 196.) 12*s.* 6*d.* net.

Science News 13. Edited by J. L. Crammer. Harmondsworth : Penguin Books, Ltd., 1949. (Pp. 162, with 2 coloured plates, 9 other plates and 26 figures.) 1*s.* 6*d.* net.

A List of Periodicals and Bulletins containing Abstracts published in Great Britain. With Appendix giving partial list of journals containing abstracts published in the British Commonwealth. Prepared under the supervision of the Abstracting Services Consultative Committee, and issued by the Royal Society, June 1949. (Pp. 62.) 2*s.* 6*d.* net.

SCIENCE PROGRESS

THE DIMENSIONS OF ANIMALS AND THEIR MUSCULAR DYNAMICS *

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A STRIKING characteristic of many small animals is the rapidity of their movements, and there have been many speculations, since the days of Galileo and Borelli, on the problem of how speed and strength are related to size. The inherent strength of a contracting voluntary muscle fibre is roughly constant, being of the order of a few kilograms per square centimetre of cross-section. The speed, however, varies enormously, a thousandfold or more, between different muscles and different animals. In general, the smaller muscles and the muscles of smaller animals are quicker. The elementary unit of muscular activity is the so-called single twitch, the rapidly reversed response to a nerve impulse : but practically all movements, and all postures, are due to contractions maintained by the fusion of successive twitches. The advantages of speed are obvious, but they must be balanced against the fact that a higher intrinsic speed entails a proportionally greater expenditure of energy in maintaining a contraction for a given time. The possibility of this great variation in speed is what has given such wide latitude of size and function in the design of animals.

A given muscle, at a given temperature and under given conditions, has a certain range of speed depending on its load. The relation between load and speed is shown by the curve marked P/P_0 in Fig. 1 [7, 8]. It is nearly invariable in shape, the scales of velocity and force being its only important variables. Force is expressed as a fraction of the maximum force P_0 developed at zero speed : velocity as a fraction of the maximum velocity V_0 against zero external force. The intrinsic strength of a muscle may be taken as P_0/A, where A is the total cross-section of its fibres : the intrinsic speed as V_0/L, where L is the mean length of its fibres.

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In a frog's leg muscle at 0° C. the intrinsic speed, V/L, is about 1·3 sec. $^{-1}$, in a tortoise's at the same temperature about 0·1. At 30° C. the speeds of both are about 20 times as great, the frog at a high temperature being a very quick animal—which is why he can jump so well : even a tortoise under a tropical sun can trot about quite briskly. In the eye muscle of a kitten the intrinsic speed is about 70 ; at a guess, in the wing muscle of a humming bird about 200. The arm muscles of a sloth or the locomotor muscles of a whale
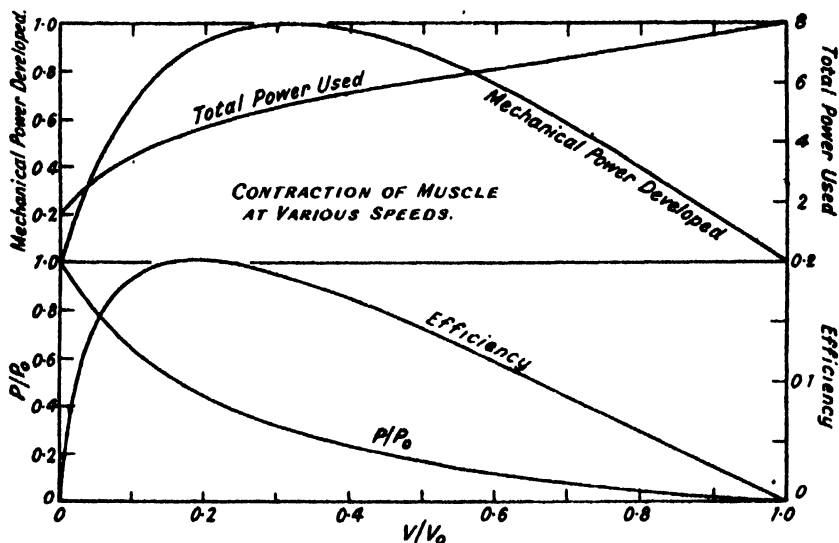
Fig. 1.—Relation between various mechanical properties of muscle and speed of shortening.

Speed V as fraction of maximum speed V_0 under zero load. Force exerted P as fraction of maximum force P_0 at zero speed. Efficiency = (mechanical work done)/(total energy used). Mechanical power = PV. Total power used = PV/(efficiency). From experiments on isolated muscles and on man.

must have a very low intrinsic speed ; the jumping muscles of a flea or the wing muscles of a mosquito an extremely high one.

The power PV developed by a muscle depends on load and speed. The curve marked " mechanical power " in Fig. 1 shows how. The maximum power occurs at about 0·3 times the maximum speed, against about 0·3 times the maximum load. It is about $\frac{1}{10}$ of the product of maximum force and maximum velocity. The mechanical efficiency, *i.e.* the ratio of work done to total energy used, also depends on the speed, its maximum value of rather over 20 per cent. occurring at about 0·2 times the maximum speed, against a load not far from half the maximum. Fortunately, these maxima of power and efficiency are rather blunt, and although their positions

are different it is possible to work at maximum power with nearly maximum efficiency—a good piece of engineering design.   At speeds, however, which are very high, or very low, both power and efficiency fall off seriously, becoming zero at both ends.

The speed at which a given muscle has to work is dictated by the functions it has to fulfil and the size of the body of which it is part.   A humming bird, while hovering, moves its wings about 55 times per second, while flying slowly backwards about 60 times, in forward flight about 75 times and in extremely rapid flight over 100 times a second [3].   The ruby-throated humming bird is said to be able to fly at 50–60 miles an hour : its developed horse-power, reckoned per unit of body weight, at this speed must be enormous compared with that of larger birds and animals ; it weighs only about 2 grams.   The sparrow moves its wings some 15 times a second, and the stork only 2 or 3 times.   These frequencies are roughly in inverse proportion to the cube roots of the weights, *i.e.* to the linear size.   If the sparrow's muscles were as slow as the stork's it would be unable to fly.   If the stork's muscles were as fast as the humming bird's it would be exhausted very quickly. These differences do not depend on nervous control, but directly on the intrinsic qualities of the muscles, and are found equally in isolated muscles stimulated electrically, though naturally they are accompanied by corresponding differences in the nervous system. The speed, in fact, of the living motor must be designed, like that of a ship, an aircraft, or a machine tool, to meet the requirements of the job.

A muscle can shorten at the same speed against a varying load by an adjustment of the number of its fibres employed.   If the load is doubled, twice as many fibres are called in by the nervous system.   The limit is reached when all the fibres are used.   Then, if the load is increased, the speed must drop according to the curve P/P_0 of Fig. 1.   So long as the speed is constant the efficiency is constant, however many fibres are employed.   In cycling, for a given length of crank, there is a certain optimum frequency of pedalling which gives the highest mechanical efficiency : with a longer crank the optimum frequency is less.   If the load is increased the optimum frequency remains the same : if the load is too great for that frequency to be kept up it is better to change gear.   The maximum power, from Fig. 1, is developed at nearly twice the most efficient frequency, but with little loss of efficiency.   Short-distance track races are won with about 2 revolutions per second, or rather more, on a high gear ; an hour's race is won with about 1·7 revolutions per second on a substantially lower gear.   At 10 miles

an hour on an ordinary bicycle, probably at nearly one's most efficient speed, one makes only about 0·8 revolution per second.

Each muscle is designed for maximum power and efficiency in its important range of speed. If that speed is exceeded the power and the efficiency fall, and the same mechanical output can be achieved only by increasing the number of fibres involved, and then at disproportionate cost. In Fig. 1, for example, unit mechanical power is developed at relative speed $V/V_0 = 0·3$, at a cost of 5·1 units of total power expended. At a relative speed of 0·6 the power developed is only 0·74, at a cost of 6·3 : if the number of muscle fibres used were increased so as to bring the power back to unity the cost would be 8·4. At a relative speed of 0·9, the cost of one unit of power would be 34.

The disproportionate cost of high speed in everyday movement is, in fact, far more serious than the calculation hitherto has suggested ; for the power required for a given type of movement usually increases as some power of the speed. In climbing a hill, for example, the mechanical power needed is proportional to the velocity ; in running or bicycling against air resistance, or in rowing a boat, it is proportional to the cube of the velocity—as indeed it is, nearly enough, in accelerating and retarding the limbs themselves in any kind of reciprocating movement, such as running. Thus doubling, or trebling, the speed from $V/V_0 = 0·3$ to 0·6, or 0·9, would raise the relative cost as follows :

Power Required	Constant.	$\propto V$	$\propto V^3$
Relative cost of doubled speed . .	1·65	3·3	13·2
Relative cost of trebled speed . .	6·7	20·1	181

A limit of speed is very soon reached.

These theoretical conclusions, based on laboratory experiments, are clearly confirmed by the performance of horses, and of human runners and swimmers. The curves of Fig. 2, constructed from world records, show how the speed has to be moderated as the duration of effort is increased. The maximum speed of human runners, about 12 yd./sec., does not appear in the figure because the maximum speed is not reached until after 4 or 5 seconds of acceleration and is not kept up for long : the total time gives only an average. The same must be true of horses running. In swimmers the shortest distance recorded is 100 yd. and considerable slowing can occur in 50 seconds : the maximum speed might easily be 20 per cent. higher than that of the 100 yd. record. In human

runners the speed has to be reduced to about 60 per cent. of the maximum if the effort is to be maintained for 5 minutes. This statement of course is over-simplified, for the records at different distances are made by different individuals ; and the typical sprinter would have to reduce his maximum speed to 50 per cent. in running a mile, the typical mile runner only to about 70 per cent. But the main effect is clear, that the higher speeds are extremely expensive and use up the available reserve of energy far faster than it can be restored by contemporary combustion.

A useful idea, in considering the muscular behaviour of animals,
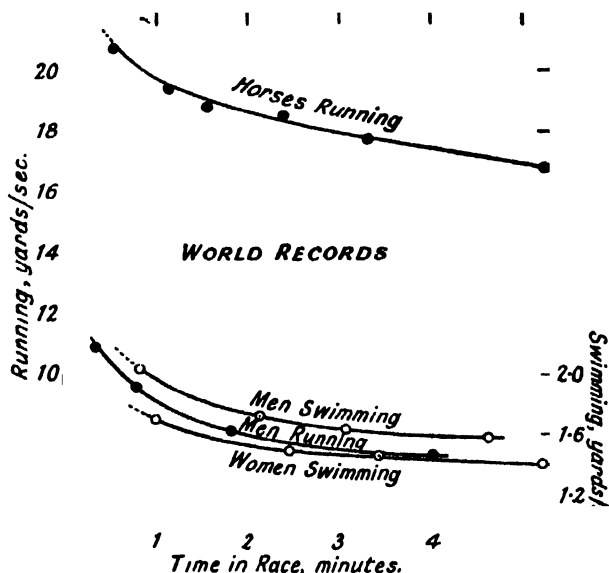
FIG. 2.—World records for running and swimming.   Average speed in a performance of given duration.

Note that the mechanical power used varies about as the cube of the speed, so that the best result is achieved by keeping the speed uniform.

is that of a series of similar animals of different size. Such similarity is most nearly approached in the cetacea--porpoises, dolphins and whales—over a 5000-fold range of weight (Fig. 3.) It cannot, for several reasons, be exact. Different animals have all specialised for some particular function, danger or opportunity : in land animals and birds gravity and inertia provide different requirements as size is altered : and the ultimate parts, the cells and tissues, do not vary in proportion to the size of the animal but depend on quite different physical and chemical factors, surface tension, diffusion and the like. But sufficient similarity does, in fact, exist

to make its discussion useful. It is assumed that similar animals
are made of similar materials, have the same shape and distribution
of organs, behave in general in the same way ; and have muscles of

Greenland

Biscayan

Humpback

Lesser Rorqual

Sei

Blue

Fin

Sperm

Bottlenose

White   Narwal

Pilot   Killer

Common Porpoise   White-sided Dolphin

Common Dolphin   Bottle-nosed Dolphin

0 1 2 3 4 5 6 7 8 9 10   15   20   25

Metres

Fig. 3.—Scale drawing of the cetacea, from common porpoise to blue whale.

the same intrinsic strength, adjusted in intrinsic speed so as to
make similar movements similarly efficient at each size. We shall
see later that dimensional reasoning, assuming a constant factor

of safety, then shows that similar animals of different size should be able to run or swim at the same linear speed and jump the same height. In the cetacea the speed that can be maintained for a considerable time is nearly the same in spite of a 5000-fold variation in weight. In land animals, to whom gravity becomes a predominant factor at extreme size, similarity is impossible over so wide a range. Let us consider first the problem of whales.

WHALES

Many observations are recorded of the speed of porpoises, dolphins and whales, and of the time during which a whale can remain under water actively swimming. The speed may be so high, and kept up so long, that such questions as these naturally arise : (1) how great is the resistance to the motion ? (2) how can the animal maintain the necessary propulsive power for long periods ? and (3) how can it get the necessary energy when, on oc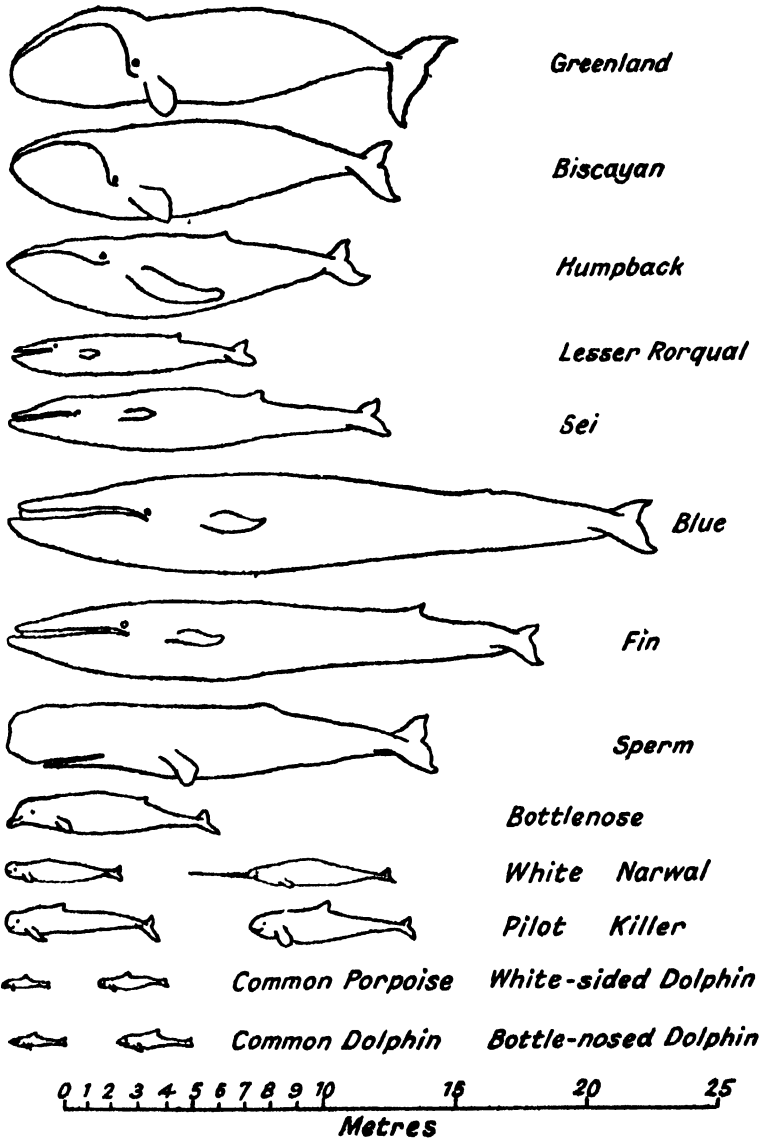casion, it does without breathing for half an hour or more ? The striking result emerges that the observed performance would be impossible unless the motion of the water past the body surface were largely laminar : and we are left with the interesting problem of how turbulence is avoided. On the physiological side we are forced to the conclusion that the rate of energy output during activity, like the basal metabolism at rest, must increase with size, not as the body weight, but less rapidly, more nearly as the body surface. If so, the time during which an animal can do without breathing should vary in general approximately according to its body length, and a whale 90 ft. long should be able to remain under water about 15 times as long as a 6-ft. man.

The resistance to the motion of an approximately stream-lined solid through a fluid can be expressed by the formula,

$$C_f \rho \text{ (total surface) } V^2/2$$

where V is the velocity, ρ the density of the fluid and C_f a number [5]. For entirely laminar flow C_f can be taken as $1.33 R^{-\frac{1}{2}}$, where R is the Reynolds number : for entirely turbulent flow C_f can be taken as $0.455 (\log_{10} R)^{-2.58}$. R is VL/ν, where L is the axial length and ν the kinematic viscosity (= viscosity/density). For low values of R the flow tends to be laminar and the resistance small, for high values of R it tends to be turbulent and the resistance great. The change-over from one state to the other usually occurs as R passes from 0.5×10^6 to 2×10^6. By very careful shaping of a stream-lined body, so as to give a favourable pressure distribution as far aft as possible, and by extreme care in manufacture both as regards

smoothness of finish and avoidance of undulation in the surface, laminar flow has been maintained up to a Reynolds number of 15×10^6. More usually, however, laminar flow occurs only over the front portion, turbulence setting in further back. The resistance, then, will lie somewhere between the two extreme values, to a degree depending on the distance to which laminar flow extends aft.

We will consider the two éxtremes (see Fig. 3) of the common dolphin (*Delphinus delphis*) and the blue whale (*Balænoptera musculus*). The dolphin seldom reaches a length greater than about 8 ft. or a weight greater than about 300 lb. The blue whale may be nearly 100 ft. long and weigh 150 tons. Nearly enough for the present purpose we may assume the following formulæ for the relation between length, weight and total surface (including fins, flukes and flippers) in the two animals (from various data provided by Dr. F. C. Fraser, and from Parry [11]).

Dolphin :
    Weight (tons) = 0·01 (length in metres)^3
    Total surface = 0·45 (length)^2
Blue whale :
    Weight (tons) = 0·006 (length in metres)^3
    Total surface = 0·40 (length)^2

Thus, a 180-lb. dolphin would be 6·6 ft. long and would have a total surface of 19·5 ft.^{2}, while a blue whale of 100 tons would be 84 ft. long and would have a total surface of 2800 ft.^{2}. In both these animals the heart is about 0·5 per cent. of the body weight, not more than in man, and the diameter of the aorta bears to the linear size of the heart about the same ratio as in man [1]. We shall see the significance of this later.

Both these animals are stated to be able to keep up a speed of 15 knots * (25 ft./sec.) for long periods, with sufficient reserve in hand to go off at 20 knots for a limited time. At 15 knots they are in what physiologists call a " steady state," like a good runner at 10 miles/hour. They are " living within their income " in respect of the oxygen required by their muscles for producing power. Let us try to calculate what this power is.

The value of the kinematic viscosity of sea water at 5° C. is about $1·63 \times 10^{-5}$ ft.^{2} sec.$^{-1}$, so R is about 6×10^4 VL. For the dolphin

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* Differences of opinion exist as to the actual speeds that can be maintained. These may be partly due to individual differences of athletic capacity between the different animals encountered : some healthy men cannot keep up more than half the speed of others. If 12 knots is substituted for 15, the following figures are changed but not the main conclusions.

6·6 ft. long moving at 15 knots (25 ft./sec.) R is therefore 10^7, so large that we should expect the flow to be largely turbulent. Let us calculate the resistance for the limiting conditions of wholly laminar and wholly turbulent flow, disregarding any possible effect on turbulence of the propulsive movements of body and flukes. For laminar flow C_f is $4·2 \times 10^{-4}$, the drag at 15 knots is 5·15 lb. wt., and the horse-power required to overcome it is 0·235. Assuming that the propulsion is as efficient as that by which a man walks up a hill, this corresponds to the effort of a man of the same weight as the dolphin climbing 2600 ft. in an hour—hard going but possible. The maximum maintained output of the most athletic man under good conditions is not more than about 0·35 h.p. For turbulent flow, on the other hand, C_f is 3×10^{-3}, the calculated drag at 15 knots is 37 lb. wt., and the horse-power required to overcome it 1·7 h.p. : this would correspond to a man climbing 18,500 ft. per hour, which is altogether impossible. If we allow 0·35 h.p. as the maximum, laminar flow must occur over 9/10 of the body surface, turbulent flow possibly over the remaining 1/10. But even this is stretching the athletic capacity of the dolphin pretty far and gives him little margin for the joyous bursts of speed which he often exhibits.

Mr. G. A. Steven of the Marine Biological Laboratory, Plymouth, who spent much time during the war in a corvette in the Atlantic, tells me that at 15 knots he has frequently observed dolphins keeping up with the ship, apparently without effort, for long periods. At the season when the sea is alive with phosphorescent protozoa, which give out light on being stirred or touched, he has frequently noticed a clear thin line of light as a dolphin approached the ship. With dolphins there was no sign of a turbulent wake : with seals, on the other hand, a large amount of turbulence was easily visible. This beautiful observation, made many times, confirms the result of the calculations.

How the animal accomplishes this engineering feat is a matter for experts in hydrodynamics. J. Gray, who discussed the matter first in 1936 [6], suggests that "rhythmic movements . . . characteristic of the body and caudal fin . . . exert an accelerating effect on the surrounding water. . . . An effect of this type may be expected to prevent turbulence in the flow of water past the body." Dr. J. F. Allen, the Superintendent of the Ship Division of the N.P.L., tells me that he is convinced that the use of the after part of the body for propulsion must reduce the pressure resistance. Whether such be the explanation or not, the difference is far too large to be explained away by any facile suggestion that the dolphin

is several times as athletic as the most athletic man ! Apart from anything else, its heart and circulation, to supply the necessary oxygen to its muscles, would have an impossible task if the flow were mainly turbulent : for its heart is no bigger than a man's.

It might be thought that in whales the problem would be easier, for the resistance, increasing approximately according to the surface, would be relatively less in relation to the mass of muscle available for propulsion. It has commonly and naturally been assumed (see, for example, [4, 10]) that the maximum horse-power is proportional to the weight of the body. For several reasons, in a series of similar animals carrying out similar movements, this cannot be so : (1) If an animal is (say) 10 times as large in linear size its movements, for the same linear speed, should occur roughly at $\frac{1}{10}$ the frequency. The intrinsic speed of the muscles must be adjusted to the greater size and lower frequency in order to obtain a reasonable efficiency. But the larger animal could develop the same horse-power per pound at $\frac{1}{10}$ the frequency of movement only by exerting 10 times the force per cm.[2] : and there are no grounds for assuming that the muscles and tissues of larger animals are intrinsically stronger than those of smaller ones. Moreover, we know as a fact that smaller animals can exert relatively greater powers than larger ones. For example, a young fox terrier weighing 29 lb., rewarded with candy at every pause [2], once ran 25 minutes in every 30 for 17 hours, up a slope of about 1 in 6 on a treadmill, climbing a total height of 75,000 ft. : the average is over 5000 ft. per hour of running time, a record quite beyond human capacity or endurance. (2) Total energy is proportional to oxygen consumption, and therefore (for a given degree of utilization) to blood flow.[*] If an animal of 10 times the linear size had 1000 times the blood flow, the linear velocity of blood in its vessels would have to be 10 times as great : for the cross-section of the aorta is relatively no larger in a whale than in man [1]. Now, according to Bernoulli's equation, in a moving fluid $(p/\rho + \frac{1}{2}v^2)$ is constant, so that the difference of pressure $(p_0 - p)$ between the cavity of the heart and the aorta (or the pulmonary artery) is $\rho v^2/2$. In an athletic man working at his maximum rate the volume of blood circulated must be of the order of 40 litres per minute, which at the height of systole must mean a linear velocity in the pulmonary artery and aorta of 2–3 metres per second. Thus, $(p_0 - p)$ can be calculated as 0·02 to 0·04 atmosphere, or 15 to 30 mm. Hg, $\frac{1}{8}$ to $\frac{1}{4}$ of his mean blood

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[*] The oxygen capacity of whales' blood is stated (e.g. [12], p. 80) to be rather higher than in smaller mammals, but not so much as seriously to affect the argument.

pressure. This is possible, though perhaps rather hard on the right ventricle. If, however, the velocity of the blood were 10 times as great the difference of pressure would be 100 times as great, viz. 2 to 4 atmospheres ! This of course is out of the question, the work of the heart would be fantastically great : and, moreover, the pressure would rise to unheard-of heights as the velocity diminished in the peripheral arteries. (3) The hearts of larger animals beat less frequently than those of smaller ones ; according to Clark * in inverse proportion to the 0·27 power of the body weight. This would make the heart rate of the blue whale about $\frac{1}{6}$ of that of the dolphin. Any engineer will appreciate that a pump weighing half a ton cannot perform as many cycles per minute as a similar one weighing a pound. Now the output per beat is proportional to the size of the heart, which is about the same fraction of the body weight in the whale as in man or dolphin. If, therefore, the frequency is only $\frac{1}{6}$, the total output per minute will be only $\frac{1}{6}$, reckoned as a fraction of the body weight. If so, the power developed also cannot be more than $\frac{1}{6}$.

Various other arguments lead to the same general conclusion. In similar animals, therefore, the maximum horse-power that can be developed during a steady effort must increase not as the weight but as some lower power of the weight, say as $W^{0·73}$ like the basal metabolism.

Let us return to the blue whale, 84 ft. long, weighing 100 tons, with a surface of 2800 sq. ft., for which analogous calculations have been made by Kermack [10]. The Reynolds number at 15 knots is about 125×10^6, which is certainly in the region where we should expect to find turbulent flow. For laminar flow C_f is about $1·2 \times 10^{-4}$, the drag at 15 knots is 213 lb. wt., and the horse-power required about 10 h.p. We have admitted a possible 0·35 h.p. for a dolphin of 180 lb. : for a 100-ton whale this would be 435 h.p., or, reducing this to $\frac{1}{6}$ in proportion to the estimated circulation rate of the blood, 62 h.p. This is six times the power required, so that, given laminar flow over the whole of the surface, the problem of the whale swimming indefinitely at 15 knots would be very easy. For turbulent flow C_f is about $2·1 \times 10^{-3}$, the calculated drag is about 3700 lb. wt., and the horse-power required at 15 knots 168 h.p.

* It is striking that Clark's formula (1) for the frequency of heart beat as a function of body weight, presumably under conditions approximating to rest, viz. $f = KW^{-0·27}$, exactly complements Brody's formula [14] relating basal metabolism to body weight, viz. $M = aW^{0·73}$, if we suppose that heart size, and output per beat, are proportional to body weight. An animal of 1000 times the weight would have 155 times the metabolism and 0·155 times the heart rate.

This is out of the question : it would need a heart and a circulation rate three times as great as can possibly be admitted. It seems therefore, that laminar flow must occur over the front two-thirds of the animal's surface, with the possibility of turbulent flow over the after one-third. Here again, as in the dolphin, we find an engineering achievement of considerable interest.

The blue whale is known to be able to swim at 20 knots for 10 minutes or so, after which its speed is reduced. Thus, for a period, it can exert considerably more power than during a long-maintained effort. This is in keeping with what we know of other animals. A man for a few seconds, as in running at top speed uphill, can develop 2 or 3 h.p. instead of the 0·5 which he can maintain for a few minutes : but he rapidly gets exhausted. The time-scale of the larger animal is longer than that of the smaller one, approximately in inverse proportion to its heart rate. The maximum speed of a human swimmer is about 2 yd. per sec. if maintained for about a minute ; it is 20 per cent. less if maintained for 5 minutes, about 25 per cent. less if maintained for a long time. If 1 minute to a man of 180 lb. is as 7 minutes to a whale of 100 tons, the whale should be able to keep up nearly its maximum speed for 7 minutes, and for very long times three-quarters of that speed.

These considerations help to make intelligible what has seemed one of the most astonishing things about whales, that they can stay below the surface swimming actively for long periods. The *Ama*, a female Japanese pearl diver, working practically without equipment, can dive to a depth of 100 ft. and remain below for as long as $2\frac{1}{2}$ minutes [13]. We know that the basal metabolism increases with size about in proportion to $W^{0.73}$, where W is body weight. We have seen that the active metabolism must be expected to increase in about the same way. Comparing the *Ama* (say 50 kg.) with a whale of 50 tons, the total oxygen used per unit of body weight should be the same in the whale in 16 minutes as in the woman in $2\frac{1}{2}$ minutes. Actually, the whale can do considerably better than that. This must be due largely to the high myoglobin content of its muscles [12, p. 80] which gives it a considerable oxygen reserve. Apart, however, from the reduction of metabolic rate with size, this oxygen reserve would not be enough to account for the very long times during which some whales can dive.

LAND ANIMALS

The general statement that similar animals of different size should be able to run at the same linear speed and jump the same height is illustrated in Tables I and II. The only exact information

TABLE I

MAXIMUM SPEEDS

(yards/second   for miles/hour multiply by 2·05)

Man . . .	12	(at about 50 yd. in sprint)
Greyhound (55-65 lb.)	18·3	(average over 525 yd.)
Whippet (20-21 lb.) .	16·7	(average over 200 yd.)
Horse (with rider) .	20·7	(gallop : average over 660 yd.)
„ (with vehicle) .	15·3	(trotting : average over 1 mile)

(Taken chiefly from Howell [9])

Ostrich . .	25	(½-mile)
Hare (L. alleni)	20	
Gazelle (Mongolian)	30	(short dash)
	20	(10 miles)
	12½	(1 2 days old)
„ (African) .	25	(¼ mile)
Roan antelope (Ergoceros)	17½	(short)
American pronghorn antelope	24	(regularly)
	29	(good conditions)
White-tailed deer (O. virginianus)	15	
American bison . .	16	
Wild donkey (E. hemionus)	20	(short)
„ „ „	15	(16 miles)
Giraffe	15	
Black rhinoceros (Diceros)	10	
Elephant (Indian)	7½	(short)
Elephant (African)	12	(short)
Coyote . . .	17	(short)
Alaskan wolf .	20	
Mongolian wolf .	17½	
Gobi wolf . .	18	(short)
Red fox (Vulpes, 8 lb.)	22	
Gray fox (Urocyon) .	20	
Cheetah (hunting leopard)	32–34	(short)

about maximum speed is for man, greyhound, whippet and race horse. The last three are very similar in general design and their speeds are nearly the same, increasing only slightly with size. The numbers given in the rest of Table I are derived mainly from observations made by improvised methods in the field. The wild donkey is similar to the horse. Wolves, foxes and hares are similar (as runners) to the dogs. The gazelles and antelopes are the most efficient and (apart from the cheetah) the fastest of all terrestrial animals : members of the family vary greatly in size. The cheetah or hunting leopard is peculiar. It is said to be extremely fast (up to 65 miles/hour) for a very short distance and to tire very rapidly. It is of medium size with limbs like those of a greyhound, with longer feet and longer heel-bone : but its thorax, housing heart and lungs, is very much smaller. It is stated to be able to outrun the fastest gazelle over a short distance ; but failing to catch it quickly, the cheetah gives up. The intrinsic speed of its muscles must be extremely high, its output of power must be enormous and therefore

TABLE II

JUMPING

(distances and heights in feet)

| | Long jump: | | |
	Running.	Standing.	High jump.
Man	26·7	about 12	6·9
Rat kangaroo (*Bettongia penicillata*) (size of rabbit)			8-ft. fence
Hare wallaby (*Lagorchestes leporoides*) (size of hare)			Over a man's head
Large kangaroo (*Macropus*) . . .	26		9-ft. fence
Jumping mouse (*Zapus insignis*) (4 in. long)		12	
Kangaroo rat (*Dipodomys*) (5 in. long)		up to 12	
Jerboa (*Jaculus ægyptius*) (4–4½ in. long)		≫ 8	
Jumping hare (*Pedetes caffer*) . .	20		
White-tailed prairie hare (*L. townsendii*)	21		
Hare			4 ft. (" spy hops ") 4-ft. obstacle
Peccary (*Pecari*)			
Mule deer (*O. hemionus*)	15–25		
White-tailed deer (*O. virginianus*) .			8-ft. fence
Wapiti			8-ft. fence
Pronghorn antelope			5-ft. fence
Impala (*Æpyceros*)	30		8-ft. fence
Horse	25		6½

exhausting, and it seems to be designed for a very short burst of speed. The gazelle, with less available power but very efficient movement, can develop almost the same velocity as the cheetah, but probably with less acceleration : at half its maximum speed it seems to be able to cruise about almost indefinitely between its feeding and watering grounds.

Looking at the animals with a maximum speed of about 50 miles/hour (25 yd./sec.) we find gazelles and antelopes, and that strange anomaly the ostrich, the fastest of all bipeds ; of about 35–40 miles/hour, hares, horses, dogs, wolves and foxes. In each group the general pattern of design is similar, but there is wide variation of size.

As regards long-jumping, kangaroos, prairie hares, horses, mule deer and the impala, a South African antelope, seem to be about equal to the record-holding man. The standing long jump of jumping mouse, kangaroo-rat and jerboa is about the same as man's, in spite of the difference of size. In high jumping the larger animals start with their centre of gravity a long way up, a fact to remember sympathetically in assessing the jumping performance of small boys.

With this in mind it is clear that the rat-kangaroo and the hare-wallaby are the best performers in the world. Large kangaroos, deer, wapiti and antelope are not much superior to man : perhaps they would be if they trained for field events with the same intensity !

One has heard it said " if a kangaroo could jump as well as a grasshopper he would be able to leap over St. Paul's Cathedral." So he would, if his muscles were intrinsically as quick as the grasshopper's and 100 times as strong as they are, and if his structure would stand the accelerations involved in taking off and landing ! These conditions are all impossible : an animal designed for high jumping with a reasonable factor of safety should in fact be able to jump the same height regardless of its size, the larger animal having the smaller acceleration and the longer take off. Indeed, as a first approximation, and often it is a pretty close one, similar animals should carry out similar movements, not in the same time but in times directly proportional to their linear dimensions. If one animal is 1000 times as heavy as another, its linear dimensions will be 10 times as great, it will take 10 times as long for one movement, but since that movement is 10 times as great its linear speed over the ground will be the same : and—here comes the advantage of size—it will take 10 times as long to get exhausted during a maximum effort. This simple statement neglects the resistance of the medium, air or water, through which it moves : but we shall see, as we have seen already for whales, that this does not affect the conclusion.

To an animal like a greyhound or a gazelle, specialised for speed, high speed presumably has provided a survival value ; certainly it must when animals are bred by man for racing purposes. It is obvious that a greyhound which could move its limbs with the same frequency as a whippet would travel about $1\frac{1}{4}$ times as fast as it does : there must be some very good reason why it cannot. The effective cause lies in the intrinsic properties of its muscles, in the characteristic relation shown in Fig. 1 between speed of shortening and load. That is a matter of the biochemical and biophysical make-up of the muscular mechanism. But what would happen if the greyhound actually did have muscles with the intrinsic speed characteristic of those of the whippet ? It would certainly be able to move $1\frac{1}{4}$ times as frequently as it does, and therefore $1\frac{1}{4}$ times as fast over the ground (with much profit to its master)—*unless*, in so doing, its structures gave way under the greater inertial stresses set up in the more rapid reciprocating movements of his limbs. The limit of speed is effected by the intrinsic properties of the muscles : but the ultimate limit, to which those properties must conform, is

set either by the need for reasonable economy in ordinary circumstances, as discussed earlier, or (in animals specialised for speed alone) by the strength of the materials—bones, tendons, joints and connective tissue—of which their bodies are built.

Athletic animals, in fact, have rather a small factor of safety, as any athletic trainer, any medical adviser to an athletic team, can testify. If a man's muscles could somehow be altered, without altering his general design, so as to allow him to run 25 per cent. faster or jump 50 per cent. higher, athletics would become a highly dangerous pastime : pulled tendons, torn muscles, even damaged bones, would be so frequent as to make it almost prohibitive. The intrinsic properties of the muscles of an athletic animal must be adjusted to the strength of the materials of which it is built.

The same relation between size and speed is found also in different muscles of the same animal. The mass of the eyelid is small, the muscles that move it are not geared up as are those of the limbs, the wink reflex must be, and is, extremely rapid : consequently, the intrinsic speed of its muscles is very high. If the muscles of the trunk were as fast as those of the eyelid two things would result ; first, there would be grave danger of structural damage when sudden movements were undertaken, and, second, the maintenance of posture would be far more expensive in energy. In the body of a single animal the various muscles vary widely in intrinsic speed in accordance with their function, those required to move light structures rapidly being rapid, those required to move massive structures slowly, or to maintain loads or postures, being slower.

Consider a pair of similar mechanisms of linear dimensions l_1 and l_2, carrying out similar movements in times t_1 and t_2. The inertial stress at any point, being force per unit area, is of dimensions $ML^{-1} T^{-2}$, or $DL^2 T^{-2}$ where D is density. Thus, assuming the densities to be the same, the inertial stresses at corresponding points are in the ratio $l_1^2/t_1^2 : l_2^2/t_2^2$. Let the two mechanisms be driven at such speeds that the inertial stresses are the same at corresponding parts : then l_1/t_1 must be equal to l_2/t_2, that is to say the linear velocity is the same at corresponding points. There is nothing new in this : it is well known that a small motor can run at more revolutions per minute than a large one, for the same reason depending on the strength of materials. Its application to animals explains why similar athletic animals of different size should, for reasons of strength of materials alone, be limited to the same linear speed, and therefore to the same height of jump.

The matter may be looked at in another simpler way. The

kinetic energy developed in a limb depends upon its mass and the square of its velocity. The mass varies as the cube of the linear dimensions, and if two similar animals were able to carry out similar movements in the *same* time the kinetic energy developed in the limb would increase as the fifth power of the linear dimensions of the animal. Now the maximum work which a muscle can do in a single contraction depends upon its size, its length and its cross-section, varying directly as its volume, *i.e.* as the cube of the linear dimensions of the animal ; so the kinetic energy developed in the limb itself would increase relatively far more rapidly than the total work which the muscle can do (as the fifth power rather than the cube). Thus, large animals might transform the major portion of the work done by their muscles into kinetic energy in their limbs. This would not do ; it would be very wasteful of energy and mechanical damage would result. If, however, the time for a given movement is not constant but increases in direct proportion to linear size, the kinetic energy, like the work done, increases only as the third power, and all is well.

We conclude, therefore, that the work done in a single movement, reckoned per unit of body weight, in producing and destroying kinetic energy in the limbs, should be the same in the large animal and the small. What happens then when there is an external load, as in running up hill or in overcoming the resistance of air or water ? For *the same speed* in the two animals, large and small, how should the external load vary with size ? Let P_1 be the load for the small animal of length l_1, with P_2 and l_2 for the large animal. The external work in a single movement is proportional to Pl : but it is also proportional to l^3 : so P is proportional to l^2. Thus the two animals can run at the same speed if the external resistance is proportional to the square of the linear dimensions. This leads to two interesting conclusions. (1) When the external load is provided by the resistance of air or water, it is proportional to the cross-section, or the surface area, of the animal and the square of the velocity. For a given velocity, therefore, the resistance P is proportional to the square of the linear size, l^2. This is exactly the relation we just calculated, so that air resistance, or a head wind, should have the same effect on the maximum speed of a whippet, a greyhound or a race-horse. (2) In running up hill, the external load is proportional to the slope θ and the weight of the animal : $P \propto \theta l^3$. But for a given speed, we have shown that P must be proportional to l^2. Hence θ, the slope, must be inversely proportional to l. If a whippet and a greyhound could run at the same speed on the flat, then the whippet could run up a slope of 1 in 6 as fast as a greyhound could run

up a slope of 1 in 9. It would be very interesting to try. One knows how fast cats can run up trees !

Assume then that at a given speed the work done in each movement, either in accelerating and retarding the limbs or in overcoming an external load, is independent, when reckoned per kilogram of body weight, of the size of the animal. The power output per unit of weight, being the product of work per movement and number of movements per second, should be greater the smaller the animal : the total power should be proportional not to the weight of the animal but to the surface—as, for quite different reasons, we saw before for whales. Now one of the problems provided by heavy exercise is that of getting rid of waste heat. The heat loss from the skin, for a given temperature difference between skin and air, is proportional to the surface of the body : that from the lungs is proportional to the amount of air breathed. The maximum power developed is roughly proportional to the surface, as we have seen : the power developed is also proportional to the amount of air breathed. Thus, with varying size, the heat loss during a maximum effort is proportional, for both reasons, to the power developed. This fortunate dispensation means that similar animals of different size taking hard exercise have exactly the same problem to face in getting rid of waste heat. It has long been known that at rest the energy requirements of an animal are proportional, not to its weight W but more nearly to its surface ; to be precise, to $W^{0.73}$. In proportion to its weight a mouse has to eat 50 times more than a horse, in order to maintain its basic activities and to keep warm. The same sort of relation, however, exists in cold-blooded animals also, the basal metabolic rate decreasing with increase of size [14]. A way to look at this is to suppose that animals live in general in a scale of time proportional, at least roughly, to their linear dimensions. If an animal is 10 times as big it weighs 1000 times as much : but its power output at work, and its energy requirement at rest, are only 100 times as great. If, however, we suppose that 10 seconds to the large animal is the same, physiologically, as 1 second to the small animal, the energy output at work and the energy requirement at rest, reckoned per kilogram of body weight, *per unit of individual time*, are the same.

This concept of physiological time cannot be exact, but it is a useful general guide. In a cold-blooded animal the physiological time-scale depends on the temperature. Raising its temperature 10° C. quickens up everything 2 to 3 times. Warm-blooded animals, in spite of many disadvantages, have the enormous advantage of a

constant time-scale. Small animals, in general, with their higher activity and their higher metabolic rate, have shorter lives, growing up and reproducing more quickly. The relation cannot be exact because the time-scale of the external world remains constant. The mouse may live at a metabolic rate 100 times that of the elephant, the humming bird at 100 times the rate of the stork : if so, on their own scale of time the day and the season are 100 times as long to the small animal as to the large. This is bound to affect their economy, as ours would be affected if nightfall and sunrise occurred every three months, if winter returned every 100 years. The fact that the physiological time-scale of an animal has to compromise with the constant time-scale of the external world, introduces an unavoidable complication : but the general guidance provided by the concept of physiological time remains valid.

We have seen that the intrinsic speed of a muscle has to vary inversely with length. The chemical engineer, therefore, in designing a muscle had to plan its enzymes and proteins so that the speed of its reactions was adjusted to the dimensions of the body into which it fitted : the smaller the body, the higher the speed required of its chemical machinery. It is still quite uncertain how that speed is determined ; indeed, the mechanism itself is unknown : but the chemical engineer, natural selection or whatever we choose to call him, has been singularly successful in his task.

As we saw earlier, two properties of muscles are opposed, speed of shortening, and economy in maintaining a force. A force is maintained by repeated stimulation and the fusion of twitches : the slower the individual twitch the cheaper the maintained contraction. Muscles suited to rapid movement are expensive for maintaining force or posture : some muscles are more appropriate to the one function, other muscles to the other, though in general each has to be used for both. A simple mechanism is provided which partly resolves this conflict. As stimulation of a muscle continues, the successive elements of response become longer in duration, so that fusion occurs at a lower frequency and a force is maintained more economically. This means, however, that a quick muscle becomes slower as fatigue sets in : and any who have run in a quarter-mile race will know that what one feels at the end is not so much exhaustion as sheer inability to move one's legs fast enough. Advantageous, therefore, as it may be for a muscle to become more economical in maintaining a contraction as stimulation is continued, there is the compensating disadvantage that if suddenly required for a quick movement it is found to be slower. It needs a certain period of recovery to become quick again. The properties

of the muscles, in this respect as in others, have to be a compromise best suited to the needs of the animal.

Maintained contractions are of special importance in connection with the statics, as contrasted with the dynamics, of animals. In land animals the dominating static factor is gravity, which is of greater importance to the large animal than to the small one. Larger animals, in fact, have to be more sturdily built. Two similar structures have weights proportional to the cubes of their linear dimensions, whereas the forces they are capable of bearing at corresponding parts increase only as the cross-sections of those parts, that is as the square of the dimensions. Thus, the weights of similar structures increase, with increase in size, in a higher ratio than the loads which the structures are suited to bear. Liberties, therefore, may be taken in the design of a small animal which are prohibited in that of a larger one. If a whale is stranded on firm ground it is suffocated and dies under its own weight.* The essential point about a large animal is that its structure should be capable of bearing its own weight and this leaves less play for other factors. In a very small animal, however, only extreme deviations could involve danger to the structure from its weight, a condition which leaves free play to other factors and corresponding high variability in design. The design of a small animal can be varied as required for functional reasons according to environment or opportunity. In a large animal, however, the design is dominated by the necessity of supporting its weight.

HEART MUSCLE

The story would not be complete without special reference to the properties of heart muscle (see Clark [1]). In this we get the clearest illustration of the principle that the speed of movement in corresponding muscles varies inversely with size. Mammals exist in a range of body weight of 1 to 40 millions, from the dwarf bat of 4 grams to the whale of 150 tons. The frequency of the heart beat has not been measured at either limit, but from mouse to elephant, from 25 grams to 3000 kg., the resting rate varies from about 700 to 25 per minute. During vigorous exercise the maximum heart frequency in the smallest active animals must run into thousands.

* Dr. F. C. Fraser tells me that some cetacean skeletons in the Natural History Museum show evidence of naturally repaired broken ribs, a sign of difficulty during temporary stranding. He reminds me that a clear correlation exists between size of animal and number of species. There are over 6000 different kinds of rodent and only two or three different kinds of elephant.

The range of size of flying birds is smaller, from the 2 grams of the humming bird to about 10 kg. which is near the limit of airborne size. The canary is stated to have 1000 heart beats per minute, the domestic goose about 80.

In mammals the heart is about $\frac{1}{200}$ of the body weight, tending to be rather larger in the more athletic animals capable of maintained effort. In birds it is greater, averaging about 1 per cent. of the body weight. The total amount of blood is generally between 5 and 9 per cent. of the body weight in mammals. The cross-sectional area of the aorta of mammals is in proportion, varying as the $\frac{2}{3}$ power of the body weight, again being rather larger in the more athletic animals, man, horse, dog and whale ; in man about 4–5 cm.[2] If the total output of the heart per minute were proportional to the body weight, the velocity in the aorta, as we have seen, would have to be so large in the largest mammals that the heart would have an impossible task. More likely the heart output per minute is proportional, not to the body weight, but to the 0·73 power of it, like the basal and the active metabolism. The heart is able, in this way, to meet requirements in a similar manner in animals of varying size.

The mechanical power developed by the heart is relatively larger in the smaller animals because of its greater frequency ; in a mouse at rest the work done by its heart per gram per minute must be greater than in a man doing maximum work. Indeed, all the dimensional relations referred to in voluntary muscle have their counterpart in the heart. The principles of similarity may not be precisely applicable in all detail, but they provide a general guide to the comparative physiology of the heart which could scarcely be found elsewhere.

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FERROMAGNETIC RESONANCE PHENOMENA
AT MICROWAVE FREQUENCIES

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1. INTRODUCTION

THE discovery of the ferromagnetic resonance effect was first reported by Griffiths in November 1946. Since that time there have been published the results of further experimental and theoretical investigations by other workers and it is the purpose of this article to give a survey of the position at present obtaining in this field.

The ferromagnetic resonance experiment provides data from which it is possible to calculate a value of the Landé splitting factor or g-value of the electron system, using equations first derived by Kittel (1947). The splitting factor is usually defined as the ratio of the magnetic moment to the angular momentum of the electron system, in units of $2m/e$ (see, for example, L. F. Bates, *Modern Magnetism*, Chap. I, Fig. 8, or E. C. Stoner, *Magnetism and Matter*, Chap. V, section 5).

The occurrence of the resonance may be understood from the following simple picture. Within a ferromagnetic material in an unmagnetised state, the individual magnetic carriers are thought of as oriented in random directions. If a steady magnetic field H is applied, sufficiently strong to saturate the material, the individual magnetic carriers line up in the direction of the field, and precess about this direction with an angular Larmor frequency, ω_L, which will depend upon H in a manner similar to that depicted by Larmor in his classical theory of diamagnetism. Suppose an oscillating field $H_1 \sin \omega t$ is now applied at right angles to H. If the frequency of the oscillating field is varied, when it is equal to the internal Larmor frequency ω_L, resonance occurs and additional energy is transferred from the oscillating field to the carrier system. Damping is present, and the resonance is not a sharp line at a particular frequency, but a broadened curve over a frequency range.

With the experimental arrangement normally used (section 2) it is convenient to express the energy dissipated in the ferromagnetic specimen in terms of the product $(\mu_R \rho)$. At the high radio frequencies employed, the permeability μ of the material is represented by the complex quantity $\mu = \mu_1 - i\mu_2$, and the quantity μ_R, which is the permeability obtained from measurements involving resistive or power loss measurements, is defined by $\mu_R = (\mu_1^2 + \mu_2^2)^{\frac{1}{2}} + \mu_1$; ρ is the electrical resistivity of the specimen.

The direct gyromagnetic measurements of Sucksmith, Barnett, Bates and others have shown that the magnetic carrier is to be identified mainly with the electron spin, contributions from the orbital motion of the electron being small in most cases. On this assumption the Larmor precessional frequency in a field H would be expected to be of the order

$$\omega_L \approx \frac{eH}{mc}$$

or
$$\nu_L = \frac{\omega_L}{2\pi} \approx \frac{eH}{2\pi mc}$$

Here e and m are the charge and mass of the electron and c is the velocity of light. Substituting the numerical values for these constants one obtains

$$\nu_L \approx 2 \cdot 80 \text{ Mc./s. per oersted.}$$

In order to be able to interpret the experimental results by the assumption of near-saturation, it is desirable that resonance should occur in fields of several thousand oersteds. Thus the resonant frequency on this simple picture must be of the order of 3000 Mc./s. or above.

Generators of electromagnetic oscillations of this order of frequency became available as a result of the extensive war-time researches, and in the so-called microwave spectroscopy of the post-war period frequencies up to about 60,000 Mc./s. have been used. It is not possible to vary widely the operating frequency of these oscillators and the experimental technique is to keep the frequency ν fixed, and to vary the applied field H, thus varying ν_L.

The resonance experiment leads to values of $(\mu_R \rho)$ for various applied field strengths H, and to the value of H for maximum power absorption, at constant frequency of the oscillating field. From this latter value, by the use of Kittel's formulæ, the Landé splitting factor or g-value of the magnetic carrier is determined. The theory of the effect is discussed briefly in section 3, after a description of the experimental arrangements employed has been given.

2. EXPERIMENTAL TECHNIQUE

The experimental requirements are :

(1) A uniform magnetic field *H*, which may be varied from zero up to several thousand oersteds and in which the ferromagnetic specimen may be placed.

(2) A generator of electromagnetic oscillations of frequency *ν*.

(3) A means of subjecting the specimen simultaneously to the steady and oscillating magnetic fields.

(4) A method of measuring the power absorbed by the specimen from the electromagnetic wave.

The block diagram of one form of apparatus is given in Fig. 1.

At the very high frequencies employed, the resonant circuit is replaced by the resonant cavity. Rectangular or cylindrical cavities are usually used, and for given cross-sectional dimensions there are
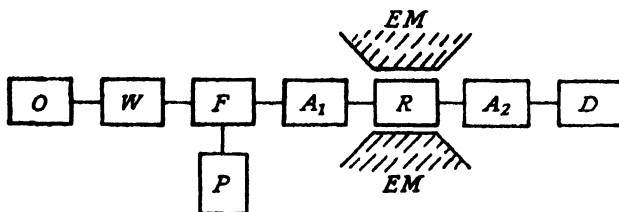

FIG. 1.—Block diagram of one form of experimental arrangement.

O = oscillator ; W = wavemeter ; F = directive feed ; P = power monitor ; A_1, A_2 = variable attenuators ; R = resonator , D = crystal detector ; EM = electromagnet pole pieces.

definite lengths to which electromagnetic waves of given frequency and field configuration are resonant. By suitable design, the circuit magnification (Q factor) of such a resonator may be high (several thousands) ; this means that the energy stored in the cavity is large, while the energy dissipated in resistive losses is small. It is thus possible to insert the ferromagnetic specimen into such a cavity and to measure the changes in energy dissipated in it, by Q factor measurements. The maximum power absorbed may be ten times that lost in the wings of the resonance absorption curve, and consequently the Q changes are usually substantial and easy to detect. At the same time, by the choice of a suitable mode (*i.e.* field configuration) the oscillating magnetic field is made more or less unidirectional over the specimen. The resonator is then placed between the poles of an electromagnet so that the specimen is in a region of most homogeneous field and is oriented so that the field due to the magnet is at right angles to the oscillating field.

Plane metallic specimens usually form one wall of a rectangular

H_{10} resonator or one end of a cylindrical cavity resonating in an H_{11} mode. When non-metallic specimens are examined, they are usually placed upon one of these same walls in a resonator made, of course, from non-ferromagnetic material. (The terms H_{10}, H_{11}, etc., refer to specific field configurations to which the cavity is resonant. For details see, for example, *Waveguides* by H. R. L. Lamont, Methuen, 1946.)

The generator used is a reflection klystron oscillator. This generates continuous waves, and the maximum power obtainable varies from about 100 milliwatts at a wavelength of about 3 cm. to a few milliwatts only, in the region of 1 cm. Each valve may be tuned through a wavelength interval of about 5 per cent. The valves operate with an anode/cathode potential difference of about 2 Kv., and this and the other electrode voltages are usually very carefully stabilised to avoid unwanted fluctuations in the generated frequency.

The valve is carefully matched to a waveguide and the generated electromagnetic wave is propagated down this to the cavity resonator, to which the wave is coupled by a small hole, critically positioned so that the required mode in the resonator is strongly excited. To the waveguide run between the valve and the cavity are coupled the various ancillaries required, such as (i) wavemeter for accurate determination of the wave-length of the oscillation, (ii) power monitor and (iii) attenuators for adjusting the generated power to the required level at the cavity.

Broadly speaking, the foregoing description is typical of all experimental arrangements so far used. It is chiefly in the method of measuring the Q of the experimental cavity that the techniques of the various experimenters differ. When the cavity is provided with both input and output coupling holes, the power transmitted with the cavity tuned to resonance is a measure of Q. In such a case a silicon tungsten crystal detector is placed across the output waveguide and the rectified current is measured. At low incident power levels (of the order of 1 microwatt) the rectified current is proportional to the incident power (Griffiths and Standley, 1949). If single coupling to the resonator is employed, the wave reflected back down the waveguide is studied, either directly by using a directive feed section in the waveguide run (Kip and Arnold, 1949) or by observing the standing wave pattern set up (Yager and Bozorth, 1947). Space does not permit the full description of these various methods and the reader is referred to the published papers of the authors quoted.

The experiment consists of measuring the power dissipated in

the specimen for a series of known applied magnetic fields, the frequency ν of the oscillating field being kept constant.   From this
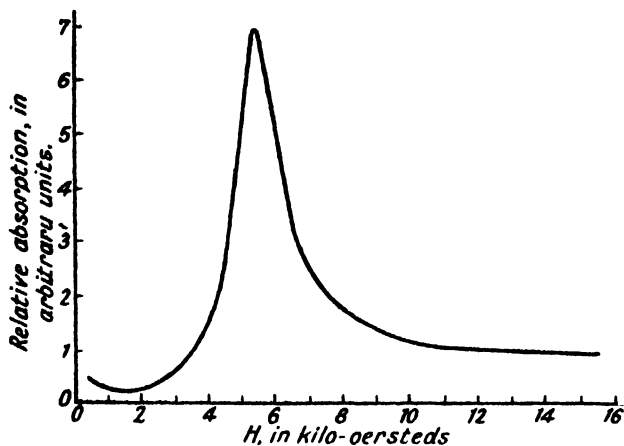

Fig. 2.—Absorption curve for a nickel specimen 1·8 microns thick, at room temperature and $\lambda = 1\cdot 23$ cm.

data, the product $(\mu_R \rho)$ is found at each field strength and, if ρ is known or found by experiment, the curve of μ_R against applied field may be drawn and the magnetic field for maximum absorption
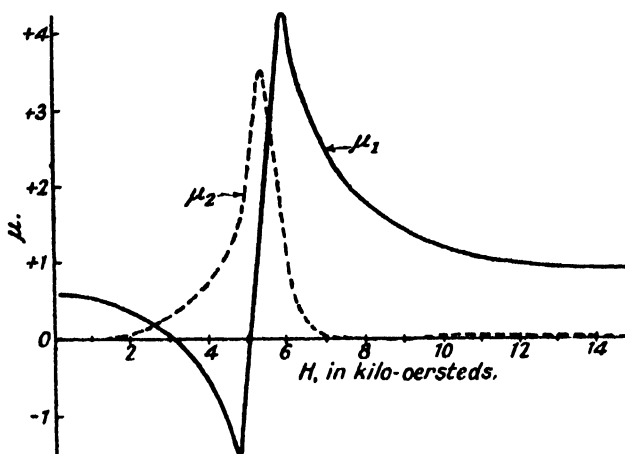

Fig. 3.—Components of the complex permeability $(\mu \cdot \mu_1 - i\mu_2)$ of a nickel specimen at $\lambda = 1\cdot 23$ cm.

found.   When interest is primarily in the shape of the absorption curve and in the resonance field, it is not necessary to calculate $(\mu_R \rho)$.   It suffices to calculate the absorption in any arbitrary units,

usually relative to that in zero applied field. An example of such a curve is given in Fig. 2.

The resonance absorption of power is accompanied by dispersion, and, as the magnetic field is varied, either the cavity or the oscillator valve must be retuned to keep the cavity resonant to the incoming signal. If this small retuning is measured, it is possible to calculate the quantity μ_L, defined by $\mu_L = (\mu_1^2 + \mu_2^2)^{\frac{1}{2}} - \mu_2$. (The permeability μ_L is that obtained from dispersion measurements, in contrast to μ_R which is derived from absorption measurements. At low frequencies, μ_R and μ_L are, in general, equal but at very high frequencies this is not the case.) Thus if μ_R and μ_L are obtained for the same specimen under identical conditions, the components μ_1 and μ_2 of the complex permeability may be separated. An example of this is given in Fig. 3.

3. The Basic Theory of the Effect

The conditions for ferromagnetic resonance to occur were first derived theoretically by Kittel (1947, 1948), and an outline of his theory will be given in this section. It is to be emphasised at once that Kittel's resonance formula appears, in the light of experimental evidence, to be a good first approximation only. Suggested corrections are discussed in section 5, following the experimental data.

On a classical model, Kittel assumes that the carriers in the ferromagnetic material are magnetic tops, for which the magnetic moment and angular momentum are parallel vectors of constant magnitudes. The magneto-mechanical ratio, γ, is defined as the ratio of the magnetic moment to the angular momentum of the top. It is also assumed that the magnetisation in both steady and oscillating magnetic fields is uniform.

The equation of motion of such a top in an applied magnetic field H is then considered. H is made up of steady (H_s) and oscillating (H_x) parts and the effects of the shape of the body are included by taking into account demagnetising corrections in the three coordinate directions.

As a result one obtains for the resonance angular frequency

(1) for a plane specimen

$$\omega_0 = \gamma(B_s H_s)^{\frac{1}{2}} \qquad . \qquad . \qquad . \qquad . \quad (1)$$

(2) for a sphere

$$\omega_0 = \gamma H_s \qquad . \qquad . \qquad . \qquad . \qquad . \quad (2)$$

The different forms of these two equations arise from the different demagnetising coefficients in the two bodies.

Substituting the value of $\gamma \left(= g \cdot \dfrac{e}{2mc} \right)$ in equation (2), one obtains for a plane specimen

$$g = \frac{21 \cdot 4}{\lambda (B_z H_z)^{\frac{1}{2}}}$$

Here λ is the free space wavelength of the electromagnetic oscillation employed and equals $\dfrac{2\pi c}{\omega_0}$. B_z and H_z are expressed in kilo-oersteds in this equation. For a spherical sample, H_z replaces $(B_z H_z)^{\frac{1}{2}}$.

Thus the ferromagnetic resonance experiment leads directly to the Landé splitting factor, or g-value, of the magnetic carrier. For an electron-spin $g = 2$, and if orbital motion also is involved, the g-value is less than 2.

In the above discussion the ferromagnetic material has been assumed to be isotropic. Kittel has also considered the effect of anisotropy forces in single crystals, with H_s and H_z along specified directions and in given planes. He has shown that the resonance condition is, in general, modified by the addition of terms involving the anisotropy constants K_1, K_2, etc. The effect is to shift the resonance, the magnetic field for maximum absorption being altered by an amount which in a cubic crystal structure, for given orientations, may be of the order of $2K_1/I$. This is about 500 oersteds in iron at room temperature.

4. EXPERIMENTAL RESULTS

It will be convenient now to discuss the experimental results which have so far been published ; the work on pure metals and alloys will be taken first, followed by that on non-metallic materials. Unless specifically otherwise stated, reference to a g-value will mean that calculated from Kittel's formula (equations (1) and (2) of the previous section).

PURE METALS AND ALLOYS

The results available to the writer are summarised in Table I. In all cases experiments were performed upon thin sheets of the ferromagnetic specimens, and this table includes only work upon samples much thicker than the depth of penetration (skin depth) of the electromagnetic wave into the metal. The skin effect, the rapid attenuation of the wave entering the metal, makes unattainable the uniform magnetisation, postulated by Kittel in deriving

TABLE I

DATA FOR METALLIC SPECIMENS

(All specimens much thicker than the skin depth at the wavelength used)

Author.	Material.	Free Space Wavelength in cm.	Temperature.	g-Value.
Yager and Bozorth (1947)	Supermalloy sheet	1·25	Room	2·17
Yager and Merritt (1949)	Heusler alloy sheet	1·25$_6$	Room	2·01
Kip and Arnold (1949)	Silicon-iron crystal (disc form)	1·26$_5$ and 3·24	Room	2·14
Griffiths and Standley (1949)	Evaporated nickel films	1·23	Room	2·16$_8$
		1·44	Room	2·19$_8$
		3·04	Room	2·27$_0$
		1·23	190° K.	2·20$_8$
		1·23	90° K.	2·35

his resonance equations. Possible effects of this varying magnetisation are discussed in the following section.

Referring to Table I, it will be seen that in all cases, except that of Heusler alloy, the g-value is greater than 2·00 by at least 7 per cent. and in the case of the experiments on nickel by Griffiths and Standley (1949) the g-value was found to vary as either the frequency or temperature was changed. The g-values greater than

TABLE II

DATA FOR THIN EVAPORATED NICKEL FILMS

Free Space Wavelength in cm.	Temperature	Transition Range in Microns.	Mean g-Values	
			Above Transition.	Below Transition.
1·23	Room	0·45 to 0·80	2·16$_8$	2·02$_9$
1·44	Room	0·52 to 0·88	2·19$_8$	2·01$_1$
3·04	Room	1·5 to 1·8	2·27$_0$	2·06$_2$
1·23	190° K.	0·5 to 0·90	2·20$_8$	2·05$_5$
1·23	90° K.	0·55 to 1·0	2·35	2·04

2·00 are unexpected, since the direct gyromagnetic measurements of Sucksmith, Bates, Barnett and others gave g-values which in most cases ranged from 1·90 to 2·00, often 2·00 within experimental error.

Further evidence has been found by Griffiths and Standley of the need for correction in applying Kittel's formula. Working with very thin evaporated nickel films, they found that at constant frequency and temperature the g-value depended upon the thick-

ness of the specimen used. Their results are summarised in Table II. The g-value was found to be greater than 2·00 and constant within experimental error for films thicker than a certain amount, t_1. When the film thickness was less than an amount t_2, the g-value was again constant and equal to 2·00 within experimental error. The transition from normal g-value to a higher value occurred over a range of thicknesses t_2 to t_1 which varied with frequency and temperature. The change in g-value was quite abrupt, as seen from Table II, and in magnitude was right outside the expected experimental error. Within the limited range of the experiments, the mean transition thickness was approximately proportional to the free space wavelength λ, and approximately equal to the skin depth δ, calculated from the formula

$$\delta = \left(\frac{\lambda \rho}{120\pi^2 \mu_R} \right) \text{cm}.$$

Here ρ is the resistivity of the film in ohm centimetres, λ is in centimetres and μ_R refers to the value of this quantity at resonance.

In an attempt to determine further factors upon which the transition thickness depended, two further experiments were carried out at $\lambda = 1 \cdot 23$ cm., and at room temperature. (1) The metal supporting the film in the resonator was changed from copper to bismuth (resistivity about 70 times that of copper). No change in the g-value for any film was found. (2) " Sandwich " specimens were prepared by sticking one nickel film on to another, the two being separated only by a very thin layer of adhesive. In each case the resonance field found was that for the upper film alone. Yet the total thickness of nickel present, as a continuous film, would have shown its resonance at a field 500 oersteds less. It thus appears that the presence or otherwise of a reflected wave in the film is not of primary importance in determining the resonance field.

Similar results were found, by these workers, for thin evaporated cobalt films, but the data are not included, as the error involved was considerably greater. This was due to uncertainty of the value of the intensity of magnetisation for each film of this magnetically hard material.

To obtain further data on the change in g-value with temperature, in nickel, Griffiths and Standley made measurements on a nickel sheet from room temperature up to the Curie Point, at a wavelength of 1·23 cm. A g-value of about 2·19 was found at 20° C., decreasing slowly to about 2·10 at 310° C. and then decreasing rapidly towards 2·00 as the temperature became close to the Curie Point. No absorption could be detected at temperatures above 350° C.

The values of the intensity of magnetisation used in the calculation were taken from the International Critical Tables, and especially below 310° C., the changes in g-value were outside the expected experimental errors.

Thus, for nickel, it seems clear that at constant frequency the g-value obtained, using Kittel's formula, decreases with increasing temperature. And yet it is understood, from a private communication, that there is no significant change in the g-value for supermalloy when the temperature is lowered to 90° K. (Yager and Bozorth).

The only detailed examination of the behaviour of single crystals has been reported by Kip and Arnold (1949). A silicon iron crystal was used, a (001) face of which had been electrolytically polished to remove surface strains. For such a plane in a cubic crystal, Kittel's resonance formula is

$$\omega_0 \quad \nu \left\{ \left[B_z + \frac{2K_1}{I} \right] \left[H_s - \frac{2K_1}{I} \cos 4\theta \right] \right\}^{\frac{1}{2}}$$

Here K_1 is the first order anisotropy constant, and θ is the angle between the magnetisation, I, and the [100] direction in the crystal. Assuming that the applied field is sufficiently great to cause saturation in its own direction, the field for resonance is to be expected to vary as $\cos 4\theta$, since $H_s \ll 4\pi I$ at the frequencies used. These were 23,675 Mc./s. and 9260 Mc./s.

This dependence of H_s upon the angle θ was very satisfactorily obeyed in the results obtained at the higher frequency. At the lower frequency, firstly, the variation was not according to a $\cos 4\theta$ law and, secondly, an additional broad resonance hump was found at lower fields, when θ was about 45°. Both these facts were shown to result from the incomplete alignment of the magnetisation along the direction of the magnetic field, which at this frequency was only a few hundred oersteds at resonance. The mean g-value found was about 2·14, but Kittel's theory of the effect of anisotropy forces upon the resonance can be considered to have been experimentally proved correct.

NON-METALLIC MATERIALS

Experimental evidence for these materials is not very extensive, and published results are summarised in Table III. The g-values accorded to Birks' experiments have been calculated by the writer ; Birks quoted only resonance fields for spherical samples and used the results as evidence for a theory of the high g-value, which is discussed in the next section.

TABLE III

DATA FOR NON-METALLIC SPECIMENS

Author.	Material.	Free Space Wavelength in cm.	Temperature.	g-Value.
Hewitt (1948) .	Zinc manganese ferrite sheet	1·25	Room	2·12
Birks (1948) .	Similar ferrite sphere	1·26	Room	2·16
	Nickel zinc ferrite sphere	3·08	Room	2·67
	Fe_2O_4 sphere	3·08	Room	2·36
	γ Fe_2O_3 sphere	3·08	Room	2·19
Bickford (1949b)	Synthetic magnetite, single crystal (disc form)	3·37	293° K.	2·17
		3·36	130° K.	2·08
		3·36	120° K.	2·06
		1·25	293° K.	2·13
		1·25	130° K.	2·09

The experiments of Bickford (1949a and b) are interesting as the first application of ferromagnetic resonance in measuring the variation of the anisotropy constant of magnetite with temperature. Working in a manner essentially similar to that of Kip and Arnold, he has examined the resonance in both natural and synthetic magnetite crystals. Each is found to have an anisotropy constant K_1 of about $- 1·0 \times 10^5$ ergs/c.c. at room temperature, becoming less negative as the temperature is lowered and passing through zero at about $-143°$ C. Working in the 3-cm. region, the resonance absorption disappeared below the phase transition in these crystals at $- 160°$ C. With synthetic crystals in the 1-cm. wavelength region, a resonance below this temperature was detected, but at a much lower field strength. Further det ·ils of this latter effect have not yet been given.

It will be seen that Bickford finds a small variation in g-value with frequency at room temperature. This is, however, within his expected error of 2 per cent. At constant frequency, his g-values decrease with decreasing temperature, whereas in nickel the reverse was found by Griffiths and Standley.

The present experimental evidence on all materials may therefore be summarised as follows :

(1) The g-values obtained by the use of Kittel's formula do not agree with the results of direct gyromagnetic experiments and are greater than 2·00 (the value for a free electron spin) by not less than 7 per cent. (The exception to this is the value of 2·01 for Heusler alloy.)

(2) In nickel and cobalt, there is evidence of an abrupt change in g-value as the thickness of the specimen is decreased below a

certain amount, which is dependent upon the frequency at which the observations are made.

(3) In nickel the g-value is found to decrease with increasing temperature at constant frequency, in magnetite the reverse is true, and in supermalloy, at low temperatures, no significant change has been observed.

(4) In nickel, the g-value increases with increasing wavelength, at room temperature. The same may be true in magnetite, but more refined experiments would be required before this could be stated certainly.

(5) Kittel's theory of the effect of anisotropy forces has been found experimentally to be correct, in the work of Kip and Arnold.

5. FURTHER THEORETICAL CONSIDERATIONS

The experimental evidence discussed in the previous section makes it clear that the theory due to Kittel is incomplete. An explanation is required of the reasons for the g-values being greater, apparently, than the free spin value of 2·00, and not constant against changes in frequency and temperature in some materials. In addition, the shape of the absorption curve and the significance of its width still require elucidation. Attempts have been made to solve these outstanding problems, but without complete success. The various suggestions which have been put forward will be briefly discussed below.

There have been five attempts differing in principle or in detail from one another, to explain the high g-value.

(1) Polder (1949) has suggested that the high g-value may be a direct consequence of spin-orbit interaction, and has developed a qualitative argument in support of this, while Kittel (1949) has recently given a semi-quantitative account of this theory. The g-value of 2·01 for Heusler alloy, obtained by Yager and Merritt (1949), has been construed as evidence in support of the theory, in that the direct gyromagnetic measurements on this material gave a g-value of 2·00 and thus indicated the complete absence of orbital contribution.

It is difficult to reconcile this explanation with the change of g-value with film thickness, found in the nickel experiments; to cover these results, it would be necessary to postulate that the interaction depended upon frequency, temperature and thickness of the specimen.

(2) Birks (1948) considers the high g-value to arise from neglecting the effect of internal strain or anisotropy fields and the experimental results quoted by him are certainly in accordance with this

suggestion. However, it is difficult to conceive the existence of such a field in supermalloy, which has very small anisotropy forces, and from which, before testing, Yager (1949) took particular care to remove artificial strains. Moreover, cold rolling this material merely broadened the absorption curve ; it did not alter the experimental g-value. Difficulties also exist in explaining the nickel results on this theory and it seems that Birks' suggestion cannot be accepted as a general explanation of the high g-value.

(3) Rado (1949a and b) has attempted to take into account interactions between the individual micro-crystals of which the polycrystalline material is made up. His argument is that these microcrystals act as single domains, and, since they are oriented at random, the additional field arising from the magnetic interaction between them cannot be parallel to each domain. There is, therefore, an additional torque acting on each domain, the effect of which must be taken into account in using Kittel's equations to derive g-values from the results of resonance experiments. A quantitative estimate by Rado of the magnitude of this correction is found to be of the right order of magnitude in some cases, but the validity of the calculation has been questioned by Brown (1949). Neither the g-value obtained for Heusler alloy nor the frequency variation of the transition observed in nickel can be explained adequately on this theory.

(4) Pryce (unpublished) has taken into account the effect of the short range exchange forces, in conjunction with the non-uniform magnetisation of the specimen which occurs usually in actual experimental arrangements. Replacing the exchange force by its equivalent magnetic field, and considering the additional torques which result, lead to an equation of motion of the form

$$\frac{1}{\gamma}\frac{\partial \mathbf{I}}{\partial t} = \mathbf{I} \times \mathbf{H} + k\mathbf{I} \times \frac{\partial^2 \mathbf{I}}{\partial y^2}$$

The second term on the right-hand side of this equation does not occur in Kittel's derivation of the resonance conditions. Approximate solutions of this equation, with the required boundary conditions, predict a change in resonance field in the right direction to account for the observed high g-value. It is not certain, however, that the magnitude of the constant k, required to account completely for the observed g-value, could be accepted theoretically.

(5) Griffiths and Standley (1949) have suggested a different interpretation of the effect of the exchange forces with non-uniform magnetisation of the specimen. If the sample is assumed to be saturated by the applied field H_z, all the carriers are oriented in the direction of this field and precess about it in cones of equal angle.

If now an oscillating field H_x is applied, at right angles to H_o, and decreasing in amplitude through the specimen, it is to be expected that the change in the angle of the cone will be greatest where H_x is greatest and will decrease to zero where H_x is zero. Thus neighbouring carriers are now at a small angle one to another, and the energy to cause this must come from the energy of the oscillating field. A kind of Bloch spin wall is formed and the energy equation for the transition is

$$h\nu_L + E = h\nu$$

where ν_L is the Larmor precessional frequency, ν is the applied frequency and E is the energy used in creating the walls which result from a single quantum absorption.

In a simple quantitative argument it has been assumed that the observed mean transition thickness, t, in nickel corresponds to just that number of carriers which can act as a single unit at a given frequency. The absorption of quanta within this unit was assumed to excite the whole thickness, a wall thus occurring at a depth t from the surface. The results of this calculation were not entirely satisfactory, but a model was employed which may be susceptible to more rigorous and complete analysis.

Much less material exists concerning the interpretation of the shape of the absorption curve. Kittel originally proposed a damping term, on purely formal grounds, and the form of absorption curve resulting from this damped equation has been found to agree well with the experimental results obtained on supermalloy (Yager, 1949) and on Heusler alloy (Yager and Merritt, 1949) with the damping constant, λ, proportional to H. A damped resonance formula of the type derived by Frenkel (1945) was, however, found to give equally satisfactory results for supermalloy (Yager and Bozorth, 1947); Macdonald (unpublished) has found similar agreement in applying the Frenkel formula to certain of the results for nickel.

Until a clear physical description of the relaxation process is obtained, it remains impossible to interpret either the constant λ of Kittel's formula or the damping frequency ν' in Frenkel's formula. Similarly the effects of spin-spin and spin-lattice interaction, familiar in the interpretation of paramagnetic resonance measurements, may not readily be included.

Finally, one further effect of damping will be mentioned, that any damping term must lead to a deviation from Kittel's formula. Or, what amounts to the same thing, in a damped resonance, the position of maximum absorption is not exactly the position of equality of internal Larmor and external applied frequencies. Such

an equality has been always assumed in calculating g-values from Kittel's formulæ. Calculations on the Frenkel model indicate that the difference in the two positions is very small and, indeed, it is not to be expected that this alone can explain the high g-value. For the supermalloy curve at a wavelength of 1·25 cm. is only 65 oersteds wide, indicating very small damping, while the nickel curve at a similar wavelength is about 2000 oersteds wide. Yet each is found to have a g-value of about 2·17.

Summarising the present theoretical position, we may say that while Kittel's theory must be regarded as no more than a very good first approximation, no fully satisfactory explanation yet exists of the discrepancies which arise from its use.

6. CONCLUSION

In the foregoing sections, the writer has attempted to survey the present available experimental and theoretical material in the field of ferromagnetic resonance. Neither the experimental technique nor the basic theory presents any major difficulties, but the complete theoretical account of the phenomena appears to be one of considerable complexity. It seems possible that each of the proposals made (section 5) may represent a different special case of a general solution, in which the effect of one or more parameters may predominate, according to the material used and the experimental conditions. Or the correct explanation may be quite different. Only further experimental and theoretical work will resolve the problem.

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THE HISTORY OF ARTISTS' PIGMENTS*

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FOR the earliest use of artists' pigments, we have to go back to pre-historic times—to a period after the last great Ice Age before Man became an agriculturist and while he still lived in the shelter of caves and eked out a precarious existence by hunting wild animals. The art of the so-called Magdalenian Period has been preserved for us, notably at Altamira in Spain, and in the Dordogne in the south of France, where the cave walls are decorated with drawings of animals of the chase, carried out in an astonishingly accurate and lively manner, in natural earth colours supplemented by black and white. Soot, chalk, and ferruginous clays were the earliest artists' pigments —pigments which have persisted throughout the ages and, in essence, are still in regular use to-day.

EGYPTIAN PIGMENTS

With this fleeting and wondering glance into the dim past, we must be content. The historical study of artists' pigments now takes us many thousands of years later to the valley of the Nile, where, from the earliest dynastics, the arts were encouraged, and artists fulfilled an important function in society by embellishing the temples and tombs which formed the centre of Egyptian civilisation and culture. One of the most interesting of these tombs, from our point of view, is the 4th Dynasty tomb of the court official Nefer-Maat, discovered by Sir Flinders Petrie at Medum in 1892 [1]. Here there are inscriptions incised and undercut in the stone and filled in with paste colours. The hieroglyphs announce that the artist " made this to his gods in his unspoilable writing "—a reference to the elaborate undercutting. The pigments were found, on examination, to be lamp black, gypsum white, ochre, powdered hæmatite (which gave both red and brown colours), and malachite green.

This was the period of the Old Kingdom, about 2600 B.C., immediately prior to the building of the Great Pyramid. More recent

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excavations have made two significant additions to our knowledge of the pigments available at this early age. The first is the blue copper carbonate azurite, and the second the celebrated synthetic frit pigment known as Egyptian Blue, which was widely used in wall paintings, and as the colouring matter of glazes, for hundreds of years thereafter. W. J. Russell [2] carried out a great deal of work on Egyptian Blue, making dozens of samples by the fusion of alkali and lime with silica and a powdered copper mineral, and he found that the conditions for obtaining a pure blue were critical around 850° C. ; any great deviations, or the presence of iron as impurity, yielded products which were green, having only a proportion of the blue colouring matter present. It remained for Professor Laurie and his co-workers [3] to establish the fact that the blue colouring matter is a definite chemical compound ($CaO.CuO.4SiO_2$) common to frit blues from ancient Egypt, Knossos, and Palestine. It is very remarkable that this Egyptian Blue, the earliest of the synthetic pigments, and one of the most difficult to prepare satisfactorily, should have been made and used more than 4500 years ago. In Egypt, all the pigments already mentioned were in general use throughout the succeeding dynasties, and were re-inforced in the 18th Dynasty (1580–1320 B.C.) by a fine golden-yellow colour made from the ground mineral orpiment, a sulphide of arsenic later to be known as " auripigmentum." Samples of mineral pigments have often been found in the tombs with the grave goods, and they are sometimes of such fine colour and quality that one feels the materials must have been specially selected for the artist's use.

As a rule, pigments from mineral sources may be easily identified, but organic materials are more difficult to recognise, especially when they are very old and faded. In the 11th Dynasty, according to Lucas [4], leather was commonly dyed red, possibly with the Persian insect dye-stuff known as *kermes* : this word, derived from the Arabic, is the source of our word " crimson." In the 12th Dynasty (2000 B.C.), linen was dyed yellow with safflower (*Carthamus tinctorius*). The more important vegetable dye-stuffs—indigo and madder—did not appear till comparatively late : indigo in the 22nd Dynasty (900 B.C.) and madder during the Græco-Roman period. Dyestuffs, however, can scarcely be included in the category of artists' pigments until such time as we find them being used in the form of lakes.

Our knowledge of the pigments of antiquity is derived from the classical writers Theophrastus, Dioscorides, Pliny, and Vitruvius ; from the various technical schedulæ and recipe books that have come down to us ; from the writings of Theophilus the Monk (eleventh

century) [5] and Cennino Cennini (fifteenth century) [6], and, not least, from the actual analysis of the materials themselves. Analysis, indeed, is essential in order to understand many of the references in ancient literature, for there is often a confusion of nomenclature which can be very puzzling. For instance, the name " minium " (red lead) was used at one time to mean either cinnabar or vermilion (mercuric sulphide) ; and cinnabar might mean vermilion, or even dragonsblood (a red gum resin from the east coast of India) ; and Thompson [7] refers to a recipe claiming to be a formula for azure blue which, when made up, results in the manufacture of vermilion !

ROMAN PIGMENTS

One of the earliest scientific examinations of artists' pigments was carried out by Sir Humphrey Davy [8] in 1815 on material which he collected, while in Italy, from the baths of Titus and other ancient Roman ruins. He obtained fragments of colour from the walls, as well as specimens of pigments found stored in pots, and among these samples he identified vermilion, red lead, various ochres, orpiment, yellow oxide of lead, a blue frit like the Egyptian Blue, copper greens, and, also, what he took to be Tyrian purple, the famous purple dye obtained from the shellfish, *Murex*, and regarded by the Romans, as well as the Greeks, as their finest colour. The blacks, and some of the browns, had a basis of carbon ; and for white, chalk and also a light clay seem to have been used. It is curious that white lead does not appear on the list, for historical records indicate that, in its synthetic form (*i.e.* the ultimate product of the corrosion of lead with vinegar), it was known from early times, and was available at Rhodes, Corinth, and Crete. Davy commented on the occurrence of lead compounds of widely varying hue (there were yellows of the massicot type varying through red to orange), and he suggested that they might have been prepared artificially by roasting white lead. Be that as it may, he found no basic carbonate of lead, as such, among his specimens. The indeterminate nature of certain of the colours on the external walls of the baths of Titus was also a subject of comment, and, although the colours were too far gone to be identifiable by chemical analysis, Davy was of the opinion that they were of organic origin, mentioning in particular indigo.

THE CLASSICAL DYESTUFFS

The two colours, indigo blue and Tyrian purple, are representatives of dyestuffs obtained from natural sources and, although the former came, as its name suggests, from a plant in India, and the latter from a shellfish in the Ægean, they are closely related in

chemical structure. Tyrian purple has a molecule like that of indigo save that, as becomes a substance from the sea, it has two bromine atoms in place of two of indigo's hydrogen atoms. Known as the Imperial purple, because it was used to dye the togas of the Roman Emperors, good qualities were scarce and more costly than indigo, in spite of the fact that the purple dye is less durable. Plants of the Indigo family are widely distributed and, as the Woad plant (*Isatis tinctoria*) also yields the same indigo blue as the indigo plant, blue became very common as a pigment as well as for dyeing purposes.

MINIATURE PAINTING

Indigo, Tyrian purple, and madder are examples of dyestuffs used extensively by manuscript painters in the so-called Dark Ages. The art of miniature painting developed about the sixth century, and had a clear run for a thousand years until the invention of printing, when it declined and, in the sixteenth century, disappeared altogether.

The liturgical manuscripts of this period are monuments to the patience of the painter and calligrapher, and they are of the utmost interest in the study of pigments, because it is in miniature painting that we find pigments used in their greatest variety. There is such diversity of colour in Persian miniatures that it is impossible to guess at the source or process of extraction of many of the pigments. As in other forms of art, the inorganic pigments are easier to identify. Lapis lazuli (the true ultramarine) and vermilion were, for the manuscript painter, indispensable—azurite, malachite, massicot, and minium being almost as important. Indeed, "minium" is the source of "miniature," a word at first restricted to mean the vignettes and ornamental flourishes found around capital letters, but now used in the widest sense to describe any small painting.

Colouring matters from the animal and vegetable kingdoms are very important in miniature painting because they are transparent and look their best on a light ground. They were used in two ways. According to the first method, the artist saturated a piece of cloth in the concentrated dye and when this had dried it constituted a convenient source of coloured ink, for it could be easily transported and made to yield its colour by soaking for a few minutes in water. The second method involved the principle of lake-making, a necessity if the dyes were to be available as artists' pigments as distinct from inks and stains.

A yellow lake that seems to have been popular with the miniature painters was made from weld or Dyer's Rocket (*Reseda*) by extracting the whole plant with alum and precipitating the concentrated extract

with an alkaline carbonate. A lake was deposited consisting of the yellow dyestuff struck on the base alumina, and this had only to be separated, washed, dried, and tempered with white of egg (glair) to be ready for use by the miniature painter. Red lakes were obtainable by the same process from the vegetable dyestuff brazilwood from Ceylon, or from the insect dyestuffs—lac from India, or kermes which may have come from the Iberian peninsula, or from Polish scarlet grain. Cochineal was not available to the old world at this early period as it derives from an insect indigenous to Mexico. Some transparent colours were of particular interest regionally ; thus gamboge, the yellow gum-resin, came originally from China, and Indian Yellow (Purrée) from Monghyr in India. The colouring principle of the latter is a salt of euxanthic acid.

BUON FRESCO

Because manuscripts are rolled up and protected from exposure, colour could be exploited for its own sake in this form of painting. In fresco painting, however, precisely the opposite considerations held. Choice of colour had to be restricted to pigments that would withstand exposure and that could be mixed with strong alkali without suffering any permanent change in appearance. This limited the fresco palette very severely. Yellow, red, and brown ochres were used, as well as a green earth and a frit blue such as had been used in Egypt. If other pigments were required, such as lapis lazuli, they had to be protected from alkali by grinding in an insulating medium, commonly an egg emulsion, and applied after the wall had dried. By the standards of the modern paint-box, this does not seem to afford an extensive range of colour, and yet some of the world's masterpieces such as Raphael's frescoes in the Vatican, and Michelangelo's ceiling in the Sistine chapel, are executed in *buon fresco*. Less formal, and more intimate, are the series of small fresco paintings by Fra Angelico in the Monastery of San Marco in Florence which, once seen, are never forgotten. Painted in the middle of the fifteenth century on the walls of a series of cells, they are, in colour and design, masterpieces of simplicity and, in their setting, extraordinarily moving in effect. In *buon fresco* the colour was applied to fresh lime plaster before it had time to dry ; in *fresco secco* the painting medium was lime water, and the word " fresco " indicates that the work was finished while the surface was still damp. One feels tempted to speculate on the possible variations that might have resulted had these artists had access to modern pigments that have a tolerance for alkali, notably the oxides of chromium and the various furnace colours which have a basis of cobalt.

EASEL PAINTING, EGG TEMPERA, AND OIL

Experiments with egg emulsion (*i.e.* with the whole egg as distinct from the white) soon demonstrated that this medium was superior in certain respects to white of egg and also to lime. Under the name of tempera painting, the egg technique was used for murals and also for the decoration of church furniture in the Middle Ages. Bright cool effects were easily obtained. Tempera was at its best when the work was executed on panels previously covered with a white gesso. Finally, such panels were painted for their own sake and resulted in what we have come to call easel painting.

Tempera painting developed in Italy, and it is the main process described by Cennino Cennini. The pigments used were the local ochres, umbers, and siennas, terra verde, Pozzuoli earth, Naples yellow, etc., supplemented by vermilion, lapis, copper greens, and blues, and a wide range of other pigments of inorganic origin. Many organic colouring matters had to be sacrificed owing to their tendency to change in hue or fade on exposure to light. Even so, tempera painting, of which we possess many superb examples in the National Gallery, is characterised by a general liveliness and diversity of colour, as seen, for example, in Benozzo Gozzoli's " Rape of Helen," where the transparency and play of light reminds one of a Persian miniature.

Panel painting was, in due course, superseded by painting on canvas. The Venetians were the first to use stretched canvas as a support for painting, but they could only proceed with this innovation after the discovery of oil emulsions which kept the paint flexible and prevented it from cracking when dry.

We have seen, from a brief survey of the main historical processes of painting, that the choice of pigments is limited by the type of art as well as by the medium in which the pigment is ground, and in this oil painting is no exception. It is essential that pigments used in this medium should be insoluble in linseed oil, otherwise disaster is sure to follow. One of the chief offenders in this respect among artists' pigments is bitumen, which is soluble in oil and has been the ruin of many a good picture. The addicts of bitumen—and Reynolds is classed among these—are the despair of the picture restorer. Many of his paintings are quite beyond redemption as, for example, " The Infant Academy " in the Iveagh Collection, Ken Wood ; the greater part of this picture has disappeared from the canvas never to return. His pallid portraits, too, demonstrate the inevitable result of using the fugitive substance carmine in the form of a thin glaze.

Equally important is the condition that oil paints should be mutually compatible, for in this medium the colours are freely mixed on the canvas, and incompatibility would result in an unsightly muddy effect. Artists, on the whole, displayed the greatest ingenuity in handling incompatibles without disaster. For example, verdigris and sulphide colours are incompatibles and yet they were used successfully in the same picture locked up in isolating varnishes which prevented chemical reaction. El Greco was particularly successful in this respect, as is evident in nearly all his paintings. In time, the old masters, who were experts in selecting, grinding, and tempering pigments as well as in using them, gradually developed a range of pigments which could be used with safety in easel painting. They acquired this ability by working through a long apprenticeship in what was virtually a studio-laboratory, long before the age of chemical invention and the advent of the artists' colourman.

PAINT IN THE CHEMICAL ERA

The year 1700 is a turning point in the history of pigments. A hundred years and more had passed since the last of the great Italians, Tintoretto and Paolo Veronese. The seventeenth century had seen the passing of Rubens, van Dyck and Teniers, Frans Hals, Cuyp and Rembrandt, Poussin and Claude, Velasquez and Murillo, and, although Hogarth and the British School had still to come, the interest at this point tends to move from the studio to the laboratory —to Diesbach's laboratory in Berlin where, in 1704, Prussian Blue was made for the first time ; an event which signalised the era of chemical invention. For various reasons, however, it took the best part of fifty years for Prussian Blue to become generally available for artists' use.

In 1751, Courtoise of Dijon first manufactured oxide of zinc, and in 1780 Rinmann found that by tincturing it with cobalt oxide he could prepare a very stable green pigment (cobalt green) which is one of our most satisfactory pigments even to-day. Gettens and Stout remark in their *Encyclopædia of Painting Materials* that " it was not until after the middle of the nineteenth century, when zinc oxide became available in large quantities, that cobalt green in turn became commercially possible." The lapse of time between the discovery of a pigment suitable for artists' use, and its appearance in painting, may be an important factor in determining the authenticity of old paintings.

In the case of cobalt blue, which Thénard first prepared in 1802 by roasting alumina with a cobalt phosphate, there was no delay

between discovery and use, for the ingredients were readily available and a good blue pigment was badly needed.

It is to the French chemist Louis Nicolas Vauquelin that we owe the discovery of chromium, so aptly christened the colour element, and it was he who first described the various lead chromates and the lemon yellows (barium and strontium chromate), and also green oxide of chromium, but it was not until exactly fifty years later (in 1859) that Guignet took out a patent for making viridian, the hydrated oxide. These compounds of chromium are among the most useful artists' pigments of all time because they provide, directly, a wide range of yellows and two very stable green colours and, indirectly, in admixture with Prussian Blue, a valuable range of greens known as the Brunswick or chrome greens. It was Vauquelin also who first analysed the vivid blue material found by Tassaert in the ovens of an alkali works, and who demonstrated that it was an artificial ultramarine. He did not, however, qualify for the prize offered by the Société d'Encouragement pour l'Industrie National for the manufacture of a synthetic blue which would have all the virtues of the famous lapis lazuli as well as being cheap and reliable. That was won by Guimet in 1828; and it is one of the accidents of scientific discovery that ultramarine should have been synthesised entirely independently and about the same time by another chemist, Gmelin of Tübingen. History, however, has since recognised that Guimet and Gmelin share the honours.

A bewildering array of new pigments was produced during the first half of the nineteenth century, and it came to be recognised that discrimination was required on the part of the artist if he wished his work to be permanent. It was the more difficult for him in that he had ceased to make his own paints, and had to rely on the professional colourmaker who was not obliged to supply pigments in accordance with chemical description or formula.

ADVENT OF ARTISTS' COLOURMAN

The artists' colourman, as he came to be called, made it his business to supply the public demand for painting materials of all kinds, but he safeguarded the interests of the artist by specialising in the production of permanent colours under laboratory control. Indeed, as long ago as 1834, the firm of Winsor & Newton (jokingly described by Thackeray as " Messrs. Soap & Isaac " !) produced a dense form of zinc oxide which they christened Chinese white, and they are also responsible for the fine yellow potassium cobaltinitrite called aureolin. Messrs. Rowney & Co. produced cobaltous stannate which they called cœruleum, a valuable addition to the palette.

Other discoveries of this half-century were emerald green and cadmium yellow. Alizarin had been isolated from madder root in 1826, and it might have been thought that the artist was now supplied with colours in full measure when, in 1856, Sir William Perkin discovered mauve, the first dyestuff to be obtained synthetically in the laboratory.

COAL TAR DYESTUFFS

The era of the coal tar dyestuffs began with mauve. A number of new dyes appeared in quick succession—magenta, eosine, and many others. The lake makers produced from eosine a treacherous pigment called geranium lake, still available commercially, but which no artist of repute would use to-day. So fugitive was this colour, and certain others of the same class, that attention was focused on the stability of painting materials in general, and especially on the resistance of pigments to fading. If a colour tends to be fugitive, this will be demonstrated most readily if it is finely ground and mixed with white or, alternatively, if it is exposed in thin washes on a white ground, as in watercolour painting. In fact, it was in this technique that attention was first drawn to the relative impermanence of certain artists' pigments.

About 1886 the fading of watercolours began to be regarded as a serious matter. Following a tremendous outburst in the correspondence columns of *The Times*, a Government enquiry was instituted, and Dr. W. J. Russell and Captain W. Abney were entrusted with the task of examining a large number of pigment washes exposed under different conditions for varying lengths of time. Meantime, the battle of words continued regarding the proper treatment of drawings, such as those of Turner, which were prone to fade. At length, in 1888, the results of the enquiry were published as a Blue Book entitled *Action of Light on Watercolours*, which comprised a physical survey of the behaviour of pigments in common use. The sequel was to have been a chemical survey which was never carried out. Sir Arthur Church, however, as Chairman of a Committee of the Burlington Fine Arts Club, continued the work. Important conclusions were obtained by a re-examination of the original test-pieces prepared by Russell and Abney. The examination was carried out after the test-pieces had been exposed continuously for thirty years, and the results were summarised by T. H. Russell, son of the original investigator, and J. Scott Taylor, chief chemist of Messrs. Winsor & Newton, under the title *The Permanence of Water-colour Pigments* [9]. They found that, after exposure for this extended period, the following colours had suffered no permanent change :

Prussian Blue, Antwerp Blue (Prussian Blue Lake), Leitch's Blue (Prussian Blue and cobalt blue), vermilion, Venetian Red and barium chromate (known as lemon yellow).

The following had largely disappeared :

Carmine, crimson lake (cochineal), Vandyke brown (a bituminous earth) and brown pink (a lake from quercitron bark).

It was further observed that there were borderline pigments that were to be avoided by artists unless they were prepared to use them in full power, that is, other than in the form of thin washes. The conclusion of the whole matter was that, apart from certain undesirable colours which should be eliminated, the artists' pigments of the period could be relied on if chosen with care and used with discretion.

DURABILITY TESTS

These enquiries, in which chemists, artists, and artists' colourmen participated, have been of the greatest service in ensuring that reliable pigments are available to the practising artist. The leading colourmen of to-day publish a chemical description of their pigments, as well as arbitrary classifications for oil and watercolour indicating which pigments may be grouped as

(1) Permanent ;

(11) Reasonably durable ;

(111) Impermanent under certain conditions.

The durability of pigment in oil is, to a greater extent than in watercolour, a function of the medium, and committees of artists and scientists, under the aegis of the Royal Academy, have made critical surveys of the colourmen's lists, concluding that they can be accepted with confidence.

RECENT PIGMENTS

Of the modern additions to the palette, the requirements of stability can be satisfied in the highest degree among the cadmium scarlets, which came into production about 1910, and in the phthalocyanin or Monastral colours, which have been known since 1938. And there are other colours, like molybdenum orange (a molybdatemodified lead chromate) dating to 1939, and perhaps manganese blue (barium manganate and sulphate) dating to 1935, that are at present of little more than theoretical interest but may well have a future in the studio. On the other side of the account, we must realise that the menace of cheap pigments will always remain, and it presents

to-day at least as serious a problem as it ever did, because it is so easy for the unscrupulous manufacturer to use organic stainers to fortify inferior colour.

We have travelled some 16,000 years down the centuries since the days when our ancestors decorated the cave walls at Altamira. As it happens, they chose colours which are permanent but, as we have seen, the history of artists' pigments concerns itself just as much with colours which have not the same degree of permanence. Pigments are chosen primarily for their hue, but, whereas the old masters took a hand in converting pigments into paint, and devised ways of using paints so as to ensure their permanence, the present-day artist is no longer interested in being a craftsman in this sense. Unable to resist the wonderful array of colours made up by the colourman, too often he overrates their durability, and needs to be reminded that the finest paintings were executed in a simple scale of traditional pigments, the limitations of material only serving to emphasise the magnificence of the achievement [10].

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ELECTROLYTIC CONDUCTION IN GLASS

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At normal temperatures glass exhibits electrical properties characteristic of an insulator, and the surface conductivity effects are usually of greater magnitude than those associated with true volume conductivity. Following the original discovery that appreciable electrical conductivity may occur in glass at elevated temperatures a considerable quantity of experimental work has been published.* It is now generally accepted that the conduction process is electrolytic in nature.

Experimental results covering many aspects of the physical behaviour of glass have encouraged a vigorous discussion * of the nature of its atomic structure. Studies of the electrical properties of glass have contributed their share to our knowledge of the vitreous state of matter and the suggestion that conduction in glass is concerned with the motion of charged ions is generally in accord with present theories of glass structure.

In recent years electrical conduction in glass has been developed as the basis of more than one industrial process, the importance of which is acknowledged in the glass industry. It is appropriate, at this stage, to outline the important experimental facts, to refer briefly to their theoretical implications and, in contrast, to mention the resulting technological developments.

The Structure of Vitreous Matter

If an attempt is made to review the experimental work in the light of modern ideas of the atomic arrangement in glass, one must first admit that, as all the work in this field is of recent origin, the theories are generally held to be of a speculative nature. However, the majority of authors have taken, as a basis for their work, a structural picture originally advanced by W. H. Zachariasen [1]. The main feature of Zachariasen's theory is his suggestion that the atoms constituting a glassy structure are arranged in a random lattice. Vitreous silica, a single-component glass (and the main

* See general references.

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constituent of many commercial glasses), with the formula SiO_2, is supposed to consist of a network of silicon and oxygen atoms with voids which, in more complex glasses, contain other atoms as in the soda-silica glass shown in Fig. 1. Each silicon atom is centrally placed with respect to four oxygen atoms lying at the corners of a tetrahedron. An oxygen atom then belongs to two such units. The satisfaction of valency requirements, which is better considered as a condition of minimum potential of each atom in the general field of interatomic forces, is thus seen to account for the occurrence of the SiO_4 tetrahedral unit. This unit invests the lattice with a certain degree of small-scale regularity. The constancy of both the interatomic distance and the angle between adjacent atom directions, a feature which is characteristic of the crystalline state, is, however, absent in a glassy structure. This results in a lack of large-scale order, to which is attributed the diffuse nature of the X-ray patterns [2] of vitreous materials. Other atoms present in the glass are assumed to lie in the larger pockets of the silicon-oxygen network. Typical glass forming oxides, SiO_2, B_2O_3 and others, give rise to the lattice network proper, while the positive

● *Silicon*   ○ *Oxygen.*   ◍ *Sodium*

Fig. 1.—Schematic representation in two dimensions of the structure of soda-silica glass.

(*After* WARREN *and* BISCOE,* *based on* ZACHARIASEN'S *theory*.)

ions from other common constituents such as the alkali oxides occupy interstitial positions [3]. The requirements which must be satisfied by potential network formers have been discussed by Zachariasen and amplified by J. M. Stevels [4]. Within the lattice structure of a glass the conditions affecting the behaviour of any atom will range from those found in polar crystals of the sodium chloride type to those in the more covalent type of crystal-lattice. On this picture it is not difficult to account for the phenomenon of electrolytic conduction in glass. It would appear possible that an

* Warren, B. E., and Biscoe, J., *J. Am. Ceram. Soc.*, **21**, 259, 1938.

interstitial ion with sufficient thermal energy might penetrate a neighbouring potential barrier in the network and migrate into another pocket, attaining a new equilibrium position. Considerations of the ionic radius and charge of an alkali ion, such as sodium, lead to the conclusion [4] that such an ion would have greater mobility than the true lattice atoms, which are subject to greater cohesive forces. On the application of an electric field the random diffusion of metallic ions is biased in the direction of the field and it is the net transfer of these ions which accounts for the passage of current through the glass. Sodium is found to be the main cause of volume conductivity in most glasses, and, in general, an increase in the sodium content of glass will be accompanied by an increase in conductivity. An account of the development of these ideas has been given by J. T. Littleton and G. W. Morey.*

Ionic Conduction

Electrical conduction in glass is accompanied by phenomena normally associated with electrolytic conduction. The occurrence of electrode polarisation effects, on the application of unidirectional fields, is readily demonstrated. Fig. 2, Plate I, shows a small bead of common soda-lime-silica glass into which were sealed two platinum wires. This bead was heated in a bunsen flame and the wires connected to a 2-volt accumulator. As the temperature of the glass increased, the glass showed greater conductivity and a current of 100 microamps was observed. This value, however, rapidly decreased and to maintain an appreciable flow of current the temperature of the bead had to be continually increased. On removal from the flame, examination showed that the platinum wire by which the current entered the glass was surrounded by small bubbles. These bubbles, which identify the anode wire, are seen in Fig. 2, and cause a decrease in the overall conductivity of the anode region. The bubbles have been found to consist of oxygen gas which is liberated in amounts in accordance with Faraday's Law [5]. A corresponding quantity of sodium (the positive ion) is deposited at the cathode. The polarisation effects can be avoided if electrodes of the " replaceable " type are used, and early workers [6] achieved success along these lines by using electrodes of sodium amalgam. The glass was in the form of a test-tube with internal and external electrodes. In this case the anode will supply sodium ions to the glass and the cathode will continually absorb the deposited metal. There is no liberation of oxygen and no polarisation occurs. It will be noticed that the electrodes are only required to exhibit

* See monograph listed under general references.

sodium solubility, and here we have evidence that the sodium ion is entirely responsible for the transit of electrical charge. The transport number of the sodium ion is thus unity, and that of the negative oxygen ion is zero.

By utilising a method originated by Burt [7] and developed by several other workers [8], relatively simple apparatus will suffice to verify the validity of Faraday's law in the case of the migration of sodium ions through glass. The circuit diagram of the apparatus is shown in Fig. 3. The glass envelope of a clear 60-watt electric lamp is the medium in which the sodium ion movement is to be studied, and is suspended with the glass bulb immersed to a depth of 1 inch below the surface of a bath of molten sodium nitrate-
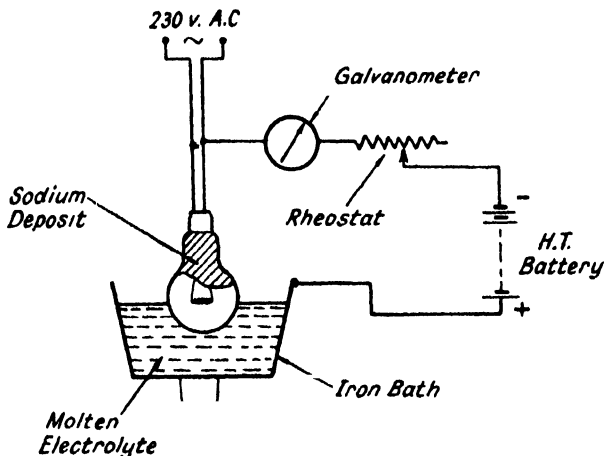
Fig. 3.—Electrolysis of sodium through the envelope of an electric lamp.

sodium nitrite eutectic. This low melting point salt mixture, contained in an iron bath, is the source of the continuous supply of sodium ions which migrate into the glass. The iron bath is the anode of a compound electrolytic circuit and is connected to the positive end of a high-tension battery, the negative end of which is connected to one of the filament leads. The filament, now the cathode, is heated by direct connection to the mains, and emits electrons which, under the influence of the applied electric field, are directed outwards and impinge on the inner surface of the bulb. The direct current circuit is now complete and if the temperature of the glass envelope is raised to about 200° C. an appreciable current will flow. The sodium ions arriving at the inner surface of the bulb are neutralised by the electrons, and pure sodium metal is

FIG. 2.—Enlarged photograph of bead showing polarisation and liberation of oxygen in glass.

FIG. 4.—Nodular deposit of sodium after electrolysis of glass.

PLATE II

FIG. 7.—Electrical welding of glass cylinders in lathe.
(*By courtesy of Corning Glass Works.*)

deposited. It is found that at the temperature in question the sodium evaporates and is deposited on the cooler parts of the bulb. A photograph of a bulb at the conclusion of such an experiment is shown in Fig. 4, Plate I, where the sodium is seen as a nodular deposit. By careful weighing, the amount of sodium deposited in the bulb can be obtained and from the known quantity of electricity used during the electrolysis the electrochemical equivalent of sodium is evaluated. In one particular experiment the author obtained a value of 0·000237 gm. per coulomb, which lies within 0·5 per cent., of the figure given by the Electrochemical Society. Several writers have used this method to support their contention that the conduction is electrolytic, but this assumes that only one metal is deposited in the bulb. It may be possible for potassium or lithium ions to migrate through the glass and form part of the metallic deposit, their place in the glass being taken by incoming sodium ions. In this case the atomic weights of the foreign ions must be taken into account before comparing the measured electrochemical equivalent with accepted values, in assessing the extent to which the process is electrolytic. In one experiment [8] no potassium was detected in the metallic deposit by spectroscopic analysis and this result adds strong quantitative evidence of the ionic nature of the conduction process.

Some time ago H. H. Poole [9] gave evidence of a non-ionic conductivity in glass. His work was carried out at room temperature using very high field strengths. It is now known that many dielectrics exhibit electronic conductivity at field intensities approaching the breakdown voltage. If it is proved that, in the presence of high potential gradients, glass conductivity departs from its otherwise purely ionic character (possibly accompanied by a deviation from Ohm's law), the value of the electrolytic conductivity theory as an explanation of the usual phenomena is not decreased. It is, for example, known that glass may emit secondary electrons under high-energy electron bombardment, and glass with high sodium content if used in high voltage rectifiers is liable to suffer electrolysis by the action of impinging electrons [10].

CONDUCTIVITY MEASUREMENTS

Measurements of the conductivity of glass are grouped into two classes, those dealing with surface conductivity * and confined to measurements in the region of room temperature, and those concerned with volume conductivity where the effects to be studied

* See comprehensive study by E. Seddon, W. J. Mitchell, and W. E. S. Turner, *J. Soc. Glass Tech.*, **23**, 197, 1939.

are intrinsic properties of the glass concerned. The latter include measurements over a wide range of temperatures and the specific resistance of the glass undergoes considerable variation. At room temperature, where glass is a typical insulator, the resistivity varies from about 10^{12} ohm cm., for a common soda-lime glass, to 10^{18} ohm cm., for vitreous silica. For the soda-lime glass this value has dropped to unity at between 1200° C. and 1400° C.

It is of interest to compare one feature in the design of the conductivity measuring apparatus which should differ at opposite ends of this wide temperature scale. When the glass possesses extremely high resistivity, care is necessary to eliminate the effect of dielectric absorption currents from the measurements. The sample of glass under examination should be long and of small cross-section so as to reduce the electrical capacity. Only direct currents can be used, for with alternating currents the half-cycle period is not sufficient to allow the full decay of the anomalous charging current—a process which sometimes takes several hours.

At higher temperatures the material is no longer a dielectric and the main requirement is to avoid electrode polarisation. In this case alternating currents are preferable. To decrease the danger of polarisation occurring during the short space of time during which the current is unidirectional, the current density is kept small. This entails the use of a specimen with high capacity—in contrast to the previous requirement.

TEMPERATURE VARIATION

The variation of the resistivity of many different types of glass has been studied over wide temperature ranges. An equation of the form

$$\log \rho = \frac{A}{T} + B$$

was originally proposed by E. Rasch and F. W. Hinrichsen [11] to express the variation of ρ, the specific resistance, in terms of T, the absolute temperature, where A and B are constants depending on the composition of the glass. Over limited temperature ranges this expression can be applied to any glass, but over wide ranges of temperature the characteristic variation of resistivity when plotted in this manner is not linear, but is of the form shown in Fig. 5. There is a small but significant curvature in the relationship at high temperatures, and it will be seen that the low-temperature resistivity is dependent on the previous heat treatment of the specimen.

If, in the high-temperature region, the actual temperature of the glass is imagined to change instantaneously, the properties of

the material will almost immediately assume values appropriate to the new temperature. However, if a similar operation is carried out in the annealing range, a measurable time interval must elapse before the final properties are apparent ; that is, before the glass is " stabilised." The stabilisation rate is very rapid at temperatures above the annealing range and is impracticably long at lower temperatures. In cooling a specimen of the glass at constant rate a temperature is reached at which the rate of cooling is of the same order as the rate of stabilisation. Below this temperature the glass will not attain full stabilisation and the temperature/property graph shows an inflection as in Fig. 5. Some sort of structural configura-
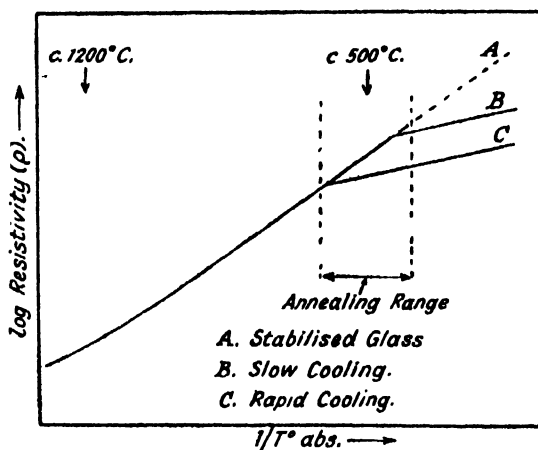
Fig. 5.—Temperature variation of resistivity.

The temperatures given are approximate and would
vary with the composition of the glass.

tion has been " frozen in " at the temperature where the inflection occurs. The rate of cooling determines this temperature below which stabilisation is not achieved and the effect on the specific resistance is shown in Fig. 5 for two different rates of cooling.

It is known that rapid cooling of glass, resulting in the formation of sharp temperature gradients during the transit through the annealing range, results in a final specimen with severe internal stress. The relatively low resistivity of chilled glass, however, is not directly associated with the presence of this stress. It can be shown that mechanical strain up to the breaking point has negligible effect on the electrical conductivity. The appearance of the anomalous conductivity variation of chilled glass is attributable to a fundamental structural change associated with the random atomic

network. The state of the theories dealing with this problem has been reviewed by G. O. Jones [12], and among the interesting attempts to explain the phenomena are those of S. M. Cox [13] and R. W. Douglas [14].

TECHNICAL DEVELOPMENTS

From the foregoing it might well be imagined that if by some means the temperature of glass is raised to the point where appreciable current will flow without the use of excessive voltages, then these currents may produce sufficient heat in accordance with Joule's law to maintain or increase the glass temperature. This is, in fact, possible and forms the basis of recent developments of great industrial significance.

It is essential that during any form of electrical heating the glass must not be subject to polarisation effects ; hence we find that alternating currents are used exclusively.

The attainment of a sufficiently high temperature is the basic requirement of two main processes which go to the making of any article of glassware. The initial process, that of melting the raw materials and the rendering of the melt homogeneous and free from gas bubbles, is one which has seen continual progress throughout the history of the glass industry. The subsequent gathering and shaping of the article is, in many cases, followed by reheating for the purpose of additional glass-forming and finishing operations. Within the last ten years striking advances have been made in both of the two processes mentioned by the direct application of electrical power to the problem of heating the glass. On the one hand, we have the ever-increasing use of electricity for the large-scale melting of glass in continuous tanks, particularly in France and Switzerland where the electrical power is available at low cost from hydroelectric sources. During the same period the Corning Glass Works in the United States have developed a remarkable process consisting of the high-frequency electric welding of glass parts for the fabrication of many types of glass apparatus.

E. Meigh has described [15] the progress of the electric melting process, from the installation of the first electrical tank (making sheet window glass) at Romont in 1938 to the present day, when large numbers of glass furnaces use electricity as a main or auxiliary source of power.

In one particular application there is no radical change in the design of the melting tank. The raw materials are fed in at one end and pass through the melting zone with flames from oil or producer gas burners impinging on the glass surface. After remaining in this

zone for the necessary fining period, the glass flows under a bridge wall into the working end of the tank, where it remains ready for gathering at a lower temperature than that required in the melting end. The modification to this type of continuous tank to effect auxiliary electrical heating consists in the addition of large graphite electrodes passing through the walls or floor of the tank and protruding for some distance into the molten glass, shown diagrammatically in Fig. 6. The conductivity of the glass is such as to permit the passage of alternating currents between the electrodes. It is most fortunate that the conductivity of the glass at temperatures necessary for melting and fining is such that normal potentials of one or two hundred volts induce satisfactory heating currents in the glass.

Variations to this type of melting tank are found. In a second
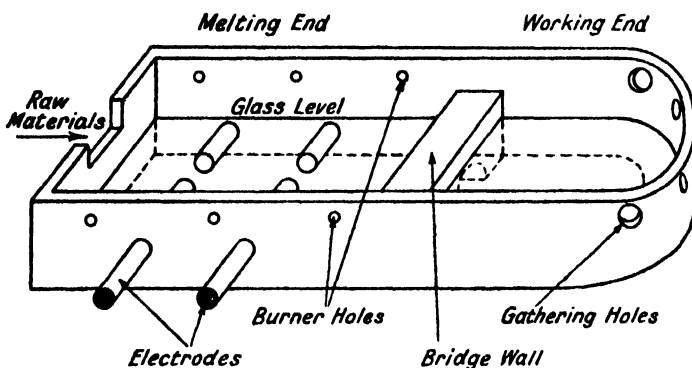
FIG. 6.—Diagram of glass melting tank with " crown " removed, showing graphite electrodes for auxiliary electric heating.

process the electrical heating is applied to the glass after it has passed from the main furnace, where it is heated by oil or gas flames, into small compartments built on to the main tank.

The advocates of electric melting claim a very considerable increase in the output of a glass melting tank when auxiliary electrical heating is applied, and the quality of the glass produced is said to be very high.

A contemporary development constituting the application of electrical heating to glass-forming and finishing operations has been made by the Corning Glass Works. The specialised techniques, which are the result of many years of intensive research, are described by E. M. Guyer [16], who emphasises the advantages to be gained over more conventional methods of glass working. It is not possible to describe here the many processes to which the technique has been applied, but we will outline the essential details of

one common operation involving the end to end sealing of two glass cylinders. When the diameter and wall thickness of the cylinders are too great for easy hand manipulation, it is usual to mount them in a glass lathe so that they rotate at the same speed. The two cylinders can be brought into contact by the operator and oxy-gas crossfire burners playing on the rotating junction heat the neighbouring glass to the necessary sealing temperature. Having effected a preliminary seal, the operator manipulates the hot glass by using relative axial movement of the cylinders and exerting slight internal air pressure, until a joint with even wall thickness is obtained. In cases where the cylinders have diameters of 12 inches or more the quantity of glass to be heated is such as to require powerful high-temperature gas burners.

High-frequency electric welding when applied to such a problem results in greatly decreased heating time and the quality and strength of the final joint shows an improvement on the results of conventional sealing methods. The powerful burners are replaced by small oxy-hydrogen flames coming from electrically insulated burners at opposite sides of the glass cylinders. The burners are connected to a powerful high-frequency generator and are maintained at an alternating potential difference of 10 kilovolts or more. The use of high frequencies for this type of work is accompanied by technical advantages and does, of course, prevent otherwise fatal accidents should the operator come in contact with the burner-electrodes.

The small flames are insufficient to melt the glass, but they do raise the temperature into the region where the glass behaves as a high-resistance conductor. At this stage the power is switched on, and the flames act as gaseous conductors carrying the high-frequency discharge from the burners to the ring of conducting glass. In a very short space of time this ring of glass is heated, by the current passing round it, to a temperature suitable for sealing. Only a very restricted zone of the glass is subject to the heating current and by adjustment of the electrical circuit very accurate control of the heating process is obtained. The small oxy-hydrogen flames act as series resistances in the heating circuit and can be adjusted to effect satisfactory matching with the generator circuits. It should be noticed that in contrast to the more usual flame-heating methods the heat is produced by the current inside the glass and deep heat penetration is achieved with even the thickest sections. The seal will be made with fewer gas occlusions than are found when the operation relies solely on the heat obtained from an external flame ; thus the electrical method results in a final joint with greater strength. In Fig. 7, Plate II, the operator is using an

insulated graphite pad to obtain a smooth outer surface in a sealing operation of the type described.

CONCLUSION

A present-day survey of the field in which use is made of electrical conduction processes in glass illustrates that the development of the subject has taken characteristic and satisfactory lines. The early results have contributed to the growth of theories of glass structure and technical operations of considerable importance have been developed. The experimental examination of the conductivity of glass under the regular variation of physical conditions covering wide ranges of glass composition is far from complete. Several writers encourage work of this nature, emphasising that, arising from an ionic process, the results will influence the further development of our knowledge of the atomic structure of glass. Admittedly the industrial developments described received considerable impetus from the urgent needs of the last war, but they do illustrate the natural application of the results of fundamental research to the solution of industrial problems. Here again, further research on the possible use of dielectric heating and induction heating in glass technology has already been reported [17].

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INTERNATIONAL CONFERENCE ON SCIENTIFIC ABSTRACTING

By L. H. LAMPITT, D.Sc., F.R.I.C., M.I.Chem.E.

FOR several years a group of persons interested in abstracting in the Medical and Allied field has been working with the object of standardising abstracting and developing collaboration between various abstracting agencies. Starting as a small meeting of about three people, aided by secretarial help offered by UNESCO and with the enthusiastic support of an officer of the Natural Sciences Division, namely, Madame Zhukova, the movement resulted in the Co-ordinating Committee on Abstracting and Indexing Medical and Biological Sciences. It may be said that this series of meetings stimulated the International Conference on Scientific Abstracting, which met in Paris under the auspices of UNESCO in June last year. As a result of the discussions, a " Final Act " has been issued, which has been published in England in *Chemistry and Industry*, and which details the result of six days' intensive study of the subject by 250 delegates and numerous " observers."

Certain points must be held in remembrance when considering this " Final Act." For example, it was stressed by the elected Chairman, Dr. Alexander King (Scientific Adviser to the Lord President of the Council), that the main consideration was the viewpoint of the user. How can that point of view be envisaged ? As it happened the most vocal representatives were librarians, and therefore there is perhaps a definite bias in this " Final Act " towards the desires of librarians, librarians in charge of vast organi-sations, mostly Government establishments. A second point is that it must be recognised that the only highly developed abstracting agencies are in the field of Chemistry ; there is nothing comparable in size, in any other branch of science, to *Chemical Abstracts* (pub-lished by the American Chemical Society) and *British Abstracts* (published by the Bureau of Abstracts). Many, therefore, of the recommendations in the " Final Act " appear needless to those who are concerned with Chemistry. A third point is that agreement had to be secured between representatives of nations well grounded

in science, and those who represented countries where science is but in its infancy. Moreover, agreement also had to be secured between chemists and botanists, geophysicists and agriculturalists, between those sciences with a comprehensive abstracting service and those with practically none. It cannot, therefore, be a source of wonder that the results are largely of a general character and deal with aspirations and ideals rather than with practical decisions.

The present situation as seen by the Conference was defined as follows :

> " There are many hundred journals containing abstracts. Some cover a wide field, others specialize. There is some duplication, yet many gaps exist. Scientists in some countries do not have direct access to enough abstracts. Information published in some languages is abstracted many times over, while that in others is insufficiently covered."

Surely the size of the problem is great, the sphere of activity vast !

Furthermore, the objectives of abstracting were defined in two sentences :

> " (a) Complete coverage by abstracts of all papers containing new information.
>
> (b) Adequate access to abstracts, both for current information and back reference, for all scientists in all countries."

But abstracting, and subsequent indexing, is only the last stage in a series of operations of which the first is the publication of the original work in a scientific journal. Consequently, much time was devoted to questions not directly concerned with abstracting, but useful to abstracting agencies in the furtherance of their work. Stressing the necessity for free intercourse of scientific literature, the Final Act requests UNESCO to continue its efforts to stimulate this exchange. It is obvious that this, the free interchange of knowledge, can be achieved by three methods, purchase, exchange and free gifts. And herein is seen the first difficulty. All abstracting services of any size are in financial difficulties, or perhaps one might say more diffidently that the economic situation is difficult. Scientific societies in this and many other countries can no longer afford to give freely of their publications, and therefore the aid of UNESCO, were it available, would be of extreme importance. Moreover, the actual cost of abstracting is a serious factor and many methods of reducing this cost were fully considered. One such method is concerned with the direct use of authors' synopses, a method disliked both by *Chemical Abstracts* and by *British Abstracts*,

but used almost entirely by *Biological Abstracts*. The " Final Act " gives cogent advice on the production of Authors' synopses and stimulates the editors of journals to develop such synopses. Herein is a great work, but it must be remembered that it throws much more strain on the already overworked editors. Editors can, however, help abstracting services by attention to the presentation of original articles, a point recognised as fundamental by the conference. Standardisation of terminology, provision of polyglot dictionaries and such like questions and a host of other minor points complicate the issue.

The user, or librarian angle was, as stated above, very much stressed. Those who have seen the brochure produced under the auspices of the Royal Society, detailing the list of journals in England which are concerned wholly or partly with abstracting, will appreciate the resolution that UNESCO be requested to promote the publication at least every five years of a directory of indexing and abstracting services, accompanied by suitable indexes, with details of title, fields of suitable indexes, type of service and many other details, and moreover UNESCO was urged to encourage the publication of a comprehensive world list of scientific publications, for the old list covered publications only to the year 1900. That such things are desirable there is no doubt, but the cost in time and money is considerable, and the more the problem is studied, the more insoluble it appears to be. One, too, is bound to consider how far all this is planning for planning's sake. The difficulty of the librarian can be understood, but there were many delegates who regarded some of the decisions as an attempt to spoon-feed the research worker. The language difficulty too was stressed. If this be looked at squarely it should not be too impossible to find a simple solution. Even English chemists a few years ago could read scientific French and German and therefore used abstracts in those languages. Why cannot therefore English, in which by far the greater proportion of new work is published, be *the* language for abstracts, and if abstracts in other languages be needed, let it be the task of the nation concerned to produce translations.

Other points in this connection which appear in the " Final Act " stress the desirability of abstracting services publishing lists of periodicals abstracted (this is done by *Chemical Abstracts* and by *British Abstracts*), UNESCO to promote publication of consolidated lists of periodicals abstracted, publications on a regional or national basis, lists of current periodicals and serial publications of the region, publications of lists of references and tables of contents.

It is perhaps well to quote in detail the recommendation regarding

Regional Committees on Abstracting, as this is concrete and may result in positive action :

> " It is recommended that UNESCO approach, through the National Commissions of its Member States or other suitable channels, scientists and abstracting agencies in each country with a view to constituting standing committees on science abstracting which would be either national or regional depending upon agreement among several countries. These committees should operate on a voluntary basis and the cost should be kept low. They should be free to correspond directly with each other, with UNESCO, with the international scientific unions and with any other bodies they choose.
>
> Their primary function would be to study abstracting with a view to ensuring adequacy. In particular their aims should be that :
>
> (*a*) Scientific publications published in their own region are adequately listed and abstracted ;
>
> (*b*) Scientists in their own region are adequately supplied with abstracts of papers published in foreign countries ;
>
> (*c*) The recommendations of this Conference are considered and implemented where possible."

It will be seen that this lays a duty on the national body represented on UNESCO. In our case it is the Royal Society which through its Advisory Consultative Committee on Abstracting has already acted, and through which the British delegates to the UNESCO Conference were briefed. It can be said quite definitely that it was the example of the British Committee which stimulated the Congress to adopt this resolution.

There is, however, the subject interest and this is covered by a further resolution :

> " Scientists and scientific publishing bodies may find it desirable to set up, in co-operation with regional or national committees where such exist, subject committees on an international level to co-ordinate abstracting in the major fields of pure and applied science. At a later date it may be found desirable to establish committees for more specialised fields.

> It is therefore recommended that UNESCO invite appropriate international bodies, including the appropriate international scientific unions, and, in the case of agriculture and applied

biology, the Food and Agriculture Organisation, to co-operate with UNESCO in setting up Subject Committees of users and publishers of abstracts of :

(a) Physics and Engineering ;

(b) Pure and Applied Chemistry ;

(c) Agriculture and Applied Biology,

to deal with abstracting problems at the international level, and that UNESCO offer these new committees facilities similar to those already provided for the Co-ordinating Committee for the Abstracting and Indexing of Medical and Biological Sciences."

The importance in the mind of the Congress of these recommendations cannot be over-stressed. Here again, the Congress had a precedent, which it admits by mentioning the Co-ordinating Committee for the Abstracting and Indexing of Medical and Biological Sciences, and in fact in a succeeding resolution it requests this body, suitably modified, to become the Subject Committee for Medical and Biological Sciences. It is perhaps well to note the four groups into which science has thereby been divided. They are (a), (b) and (c) above, together with Medical and Biological Sciences. It is recognised there must be overlap, but a moment's thought will convince that this is inevitable. One of the most important suggestions is that W.H.O. (World Health Organisation) and F.A.O. (Food & Agriculture Organisation), both of which rank equally with UNESCO in the UNO hierarchy, are requested to join in the colossal work to be undertaken.

It will be noted that one of the branches is Physics and Engineering. The Congress went very far with this branch and called for an international committee to be set up forthwith to implement the idea that, under the auspices of a single internationally controlled organisation, be published a " single international general abstracting journal for physics, both pure and applied, including astrophysics and the geophysical sciences and for such branches of engineering as it may be appropriate to include." It will be interesting to await the outcome of this idea and what steps will be taken to finance such a large undertaking.

It was obvious from the opening remarks that the object of UNESCO was to set up a body to control *all* abstracting, but the criticisms of the chief U.S. delegate, supported by the British delegation, left no doubt in the mind of the organisers that this idea must be dropped and dropped it was immediately ; hence the recommendation :

" It is recommended that UNESCO act as a clearing house, to provide a channel of liaison, and to facilitate the implementation of the resolutions of this Conference."

It must be admitted that no one is bound by these decisions and that UNESCO through its Continuing Committee, chosen by UNESCO secretariat from a number of people elected by the Conference, may take any unilateral or independent move it may choose, and in fact the final resolution of the Conference requests UNESCO so to act by suggesting they consider the financial aspects.

This final resolution may perhaps be quoted as exemplifying the whole indefinite character of the recommendations of the Conference :

" Since abstracting is very important for the dissemination of scientific information, the attention of UNESCO, W.H.O. and F.A.O. is drawn to the resolutions of this Conference and they are asked to consider the provision of the financial means needed to implement the recommendations of this Conference and also to provide for better distribution of abstracts of subjects which are the special concern of these Agencies, to areas where the application and development of science is being retarded by lack of abstracts."

RECENT ADVANCES IN SCIENCE

ASTRONOMY. By MICHAEL W. OVENDEN, B.Sc., F.R.A.S., University Observatories, Cambridge.

DIFFUSE NEBULÆ AS SOURCES OF RADIO EMISSION.—In a previous article of this series (SCIENCE PROGRESS **37**, 475, 1949) a brief summary was given of the observations of discrete sources of radio emission, and the suggestion made that a possible source of such radiation might lie in high-temperature gaseous stellar envelopes of low visual opacity. Almost simultaneously with the publishing of this article, a letter appeared in *Nature* by Bolton, Stanley and Slee indicating that within the errors of their observations the positions of three of these sources coincided with nebulous objects.

At the Australian Council of Scientific Research, Division of Radiophysics, observations of these discrete sources of radio emission have been made concurrently with, and independently of the British work, following somewhat similar lines. The interference technique employed to obtain resolution is an interesting variant on the method described before, which used two aerial systems. Details of the method which uses only one aerial system have been published by Pawsey, Payne-Scott and McCready (*Nature,* **157**, 158, 1946) and Bolton and Stanley (*Nature,* **161**, 312, 1948 ; *Aust. J. Sci. Res.,* A, **1**, 58, 1948). The interference is obtained between a directly received beam, and a beam reflected off the sea, the aerial system being mounted on a high cliff, and the source observed at rising or setting. The progressive change in path difference between the two rays as the altitude of the source varies with time gives rise to a succession of maxima and minima to the combined received signal. The method is thus the radio analogue of the familiar Lloyd's Mirror experiment of elementary interference optics.

Measurement of the times of occurrence of the successive maxima and minima enable the actual track of the source above the horizon to be deduced, from which the celestial co-ordinates may be immediately obtained. The accuracy of measurement of position would appear to be of the order of 30 seconds of time in R.A., and 10' arc in Declination, the accuracy depending to some extent upon the

position of the source ; the accuracy is thus of the same order with both interference methods.

The variable source of radio emission in the Cygnus region has been extensively examined by this method (*Aust. J. Sci. Res.*, *A*, **1**, 58, 1948), on frequencies of 60, 85, 100 and 200 Mc./s. The presence of a constant and a variable component is apparent, the constant component having a spectral maximum at 100 Mc./s., while the intensity of the variable component is not detectable on 200 Mc./s., but increases rapidly with decreasing frequency. The periodicity decreases with increasing frequency, and, although there is no correlation found between these variations on frequencies as close as 85 and 100 Mc./s., the general level of activity of the variable component shows good correlation between all the frequencies. The behaviour of the variable component is compared with that of enhanced solar radiation which probably originates in the corona : while the lack of correlation between variations at different frequencies is also apparent, in the case of the enhanced solar radiation the spectral distribution is different, the variations being more pronounced at higher frequencies.

The use of this method of interference requires a carefully chosen geographical location. A quantitative upper limit to the angular diameter of the source can be obtained, since the ratio of the intensities of the maxima and minima is a function of the angular width, the greater the width, the greater the proportion of received signal which is thrown into the minima. It is this effect which produces the peculiar limitation of these interference methods already mentioned, that the greater the density of the discrete sources, the less the likelihood of their being recognised as individual sources. In the case of the Cygnus source, an upper limit of 8' of arc can be set to the width, although the true width may well be much less than this.

A systematic survey of a quarter of the celestial sphere has been made with this apparatus on a frequency of 100 Mc./s., the mean sensitivity being of the order of 10^{-24} watts m.$^{-2}$ (c./s.)$^{-1}$, and six sources in addition to the Cygnus source have been isolated (*Nature*, **162**, 141, 1948). In no case has the angular width been greater than the experimental limit, which varies in individual cases from 1° to 8' of arc. Of these sources, three are variable, three constant and one unclassified.

In a further note (*Nature*, **164**, 102, 1949) Bolton, Stanley and Slee have shown that the positions of three of the more intense of these sources coincide, within the experimental error, with the nebulous objects NGC 1952, 4486 and 5128. The first of these is the well-known Crab nebula. Believed to be the expanding shell

of the supernova of A.D. 1054, the object at the present epoch is about 4′ × 6′ in angular dimensions, only a little less than the experimental limit of diameter determination. If the nebula is in fact the source of the emission, non-thermal mechanisms must be invoked, as the effective temperature deduced from the radio observations is of the order of a million degrees, while the temperature of the nebula has been estimated as only 50,000° (Minkowski, *Astrophys. J.*, **96**, 199, 1942). The other two objects have a more uncertain nature, and, while they are usually classed as extra-galactic nebulæ, they do show anomalous features, and have yet to be resolved into stars; it is suggested that the radio observations indicate a galactic nature. Uncertainties of identification of this nature are not uncommon, especially in the southern hemisphere, where the shortage of telescopes of large aperture, while being rectified, is still acute. Some support is lent to the suggestion of Bolton and Stanley by the discovery by Evans (*M.N.R.A.S.*, **109**, 94, 1949), during a survey of southern nebulæ with the 74-inch at Pretoria, that NGC 5128 is in fact a diffuse nebula of the Crab type. Before real confidence can be placed in the identification of diffuse nebulæ as sources of radio emission, many more coincidences of position must become apparent, but, should future observation confirm the present suggestion, radio methods may yet prove more effective than large telescopes in distinguishing in doubtful cases between galactic and extra-galactic nature, a strange irony of nature since, by optical standards, the resolution of the radio telescope is extremely poor.

STELLAR " FLARES."—A very different suggestion for the origin of these radio emissions has been put forward by Unsöld (*Nature*, **163**, 489, March 1949). From an analogy with the radiation from the disturbed sun, he believes that the sources may well be unusual stars of low luminosity and low temperature, which suffer large-scale disturbances similar to solar flares, but covering much greater areas of the star's surface; stars of spectral type M which show emission lines (primarily of ionised calcium) are likely choices. It is known that dwarf M emission stars (dMe stars) do sometimes show sudden short-duration increases in brightness, which are referred to as " flares," although the analogy with solar flares is not to be pressed too far without further observation. An accurate photo-electric light-curve of such a " flare " on dM4e star has recently been published by Gordon and Kron (*Pub. Astr. Soc. Pacific*, **61**, 210, October 1949). The general shape of the curve does show a general similarity to the development curves of solar flares, although the observations of the star were taken in the green region of the

spectrum, and not near Hα where solar flares are most prominent. From the rate of loss of luminosity during the decay portion of the curve, a relationship between the area of the star involved in the eruption and the rise in temperature may be deduced ; if the whole visible area of the star brightened, a temperature rise of only 40° K. would be required. However, spectrographic observations by Joy and Humason (*Pub. Astr. Soc. Pacific*, **61**, 133, June 1949) on another variable dM4e star show a conspicuous brightening of the continuum spectrum in the blue, which requires a much greater temperature change. Gordon and Kron conclude that an area of the star only 0·005 per cent. of the entire sphere was involved ; with solar flares, relative areas of one-tenth of this are sometimes attained, and so the phenomena are at least comparable in area. This peculiar behaviour of dwarf M emission stars is important, not only for its intrinsic interest, but for a possible (although at the present stage highly tentative) relationship to radio observations.

THE NATURE OF THE SURFACE OF THE MOON.—From the same laboratory in Australia has come a paper entitled " Microwave Thermal Radiation from the Moon " (Piddington and Minnett, *Aust. J. Sci. Res.*, A., **2**, 63, 1949), in which interesting conclusions on the temperature distribution in the outer layers of the moon, and the nature of the lunar surface material, have been derived.

The heat radiation which is here examined has a wavelength of 1¼ cm. The main receiving apparatus was a parabolic reflector of 44 inches diameter mounted equatorially. The width of the receptor cone to half intensity was ¾°, and accurate setting of the receiver could be made by a visual finder. A rotating disc enabled a comparison to be made twenty-five times a second between the radiation received by the aerial and the thermal radiation of an absorbing disc at a known fixed temperature. With the stated aerial width, some resolution over the disc of the moon is possible, and lunar temperatures calculated on the basis of maximum aerial gain are less than the true average temperatures ; correction can be easily applied.

Measurements have been made over three complete lunations, and the resultant temperature variations of the receiver can be represented by a sine wave which has a phase lag of 45° with respect to the phase angle of the moon. With the aerial always aligned on the centre of the lunar disc, the mean average lunar temperature, and the mean equatorial temperature can be calculated : values of 239° K. and 249° K. respectively are given, estimated accuracy being ± 5 per cent. and amplitudes of variation ± 52° K. and ± 40° K. respectively.

Observations of lunar thermal radiation in the long infra-red region about 10 microns wavelength have frequently been made with thermocouples—indeed, since the time of Lord Rosse, who first used a thermocouple in this way. In some ways the thermocouple has the advantage; it is simpler to use, and does not suffer so much external disturbance; in the radio observations, the presence of surface winds may vitiate the readings. The radio method is, however, incomparably more accurate, especially for low temperatures. Lunar temperature changes of only 8° K. could be detected, and, since the Rayleigh-Jeans law of distribution of thermal radiation applies in the microwave region, very low temperatures may be measured; thermocouples could not detect radiation from the moon if its temperature were below 100° K. Some difficulty also arises with the thermocouple in distinguishing between reflected solar radiation and true lunar thermal emission. The most reliable thermocouple experiments are those of Pettit (*Astrophys. J.*, **81**, 17, 1935) with which the radio observations are compared. A significant difference is immediately apparent, in that the infra-red curve of variation of temperature with lunar phase angle shows a temperature in phase with the lunar cycle. The difference is probably due to the face that the surface material of the moon is opaque to radiation in the 10μ region, but partially transparent to centimetric waves. The initial energy falling on the surface travels into the crust of the moon as a temperature wave, and, while the thermocouple only measures temperatures actually at the surface, the radio readings are an integral of the radiation from all surface layers from which the radiation can escape; this depth has been estimated as about 40 cm. When the radio observations are interpreted in this way, they yield a temperature for the interior of the moon of 234° K. (which is constant) and an average surface temperature for the new moon of 145° K. The accuracy of the final deductions is believed to be better than ± 10 per cent.

An analysis of the penetration of temperature waves into a solid with constant thermal conductivity and specific heat leads to an expected sinusoidal temperature variation, but the phase lag is less than 45°, tending to this figure only as the depth of penetration of the radio waves becomes so great that the region of constant temperature is reached. However, in the present case, a lag of 45° is apparent while the amplitude of the thermal oscillation is still an appreciable fraction of the surface value; a model whose thermal properties vary with depth is thus required. The general case is difficult to analyse, but a simple satisfactory model is that of a thin layer of dust covering the lunar surface. This model is examined,

and the radio results found to be consistent with a layer of dust of the order of 1 mm. thick.

Polarisation measurements on moonlight have already suggested the possibility of such a layer (*e.g.* Wright, *Proc. Nat. Acad. Sci.*, **13**, 535, 1927), and further evidence has been obtained from thermo-couple readings taken during a lunar eclipse. It is interesting to compare the results of Piddington and Minnett with those of Wesselink (*Bull. Astr. Inst. Netherlands*, **10**, 351, 1948) who analysed the thermocouple observations of a small area near the centre of the lunar disc during the eclipse of October 28, 1939, by Pettit (*Astrophys. J.*, **91**, 408, 1940). During an eclipse, the penetration of the heat wave is only a few millimetres. The temperature in the interior of the moon is calculated to be 212° K., in reasonable agreement with the value of 234° K. cited above. The thermal conductivity of the surface material is given as 16×10^{-5} cal. cm.$^{-1}$ min.$^{-1}$ (° C.)$^{-1}$. Such a low conductivity would seem to point directly to a powdered material, for, in the virtual absence of an atmosphere, the only means of heat transport in such a powder is by conduction from grain to grain through the contact areas, and through the interstices by radiation. Wesselink uses laboratory observations by Smolu-chowski (*Bull. Acad. Sci., Cracovie, A*, **129**, 1910 and 548, 1911) to deduce an upper limit to the diameter of the surface grains of 0·3 mm. Again the agreement with the radio results is good. The combination of polarisation experiments on visible radiation and temperature measurements with infra-red and microwave radiations may be said to have provisionally established the existence of such a dust layer on the surface of the moon.

A POSSIBLE LUNAR ATMOSPHERE.—The existence of a layer of dust a millimetre thick on the lunar surface finds a ready explanation in the fall of meteoric bodies, as calculations by Watson (*Between the Planets*, 1945) on the basis of the occurrence of meteors in the earth's atmosphere show. For the explanation to be valid, how-ever, it is required that there be no atmosphere on the moon capable of offering appreciable protection against meteoric bombardment.

Kinetic theory calculations indicate that the moon could not retain an appreciable atmosphere of the lighter gases for cosmic periods of time, but experimentally it is only possible to set a lower limit to the density of a hypothetical lunar atmosphere. From the observations of occultations it can be shown that the horizontal refraction of the lunar atmosphere cannot exceed 2″ of arc, indicating that any lunar atmosphere must have a density at the moon's surface less than 1/2,000 that of the earth's atmosphere at sea level. If the lunar atmosphere were more dense than about 10^{-4} that of the

earth, the twilight zone of the moon under full illumination should be as noticeable as the earth-shine on the dark part of the moon.

In 1943, Fessenkoff (*Astr. J. Soviet Union*, **20**, 1, 1943) proposed a much more sensitive method of detecting a lunar atmosphere. When the moon is observed at quadrature, the background illumination will consist of three parts, (*a*) light scattered in the earth's atmosphere, forming an ordinary lunar halo ; (*b*) light reflected to the moon from the sunlit hemisphere of the earth, and (*c*) light diffracted in the lunar atmosphere. Component (*c*) should be polarised, and hence the degree of polarisation of the background illumination should be $2c/(a + b)$. Observation of sky brightness near the sun, from which can be computed the brightness of the lunar halo in quadrature, enables the ratio of the masses in unit vertical columns of the lunar and terrestrial atmospheres to be expressed in terms of the degree of polarisation, r, the numerical form of the relationship being $m/M = 0.196 \times 10^{-4} r$. With polaroid analyser, Fessenkoff was unable to detect any polarisation, from which he deduced on the basis of laboratory tests that $r < 0.04$, or $m/M < 10^{-6}$.

Fessenkoff's experiments have, however, recently been repeated with greater precision by Lipski (*Dokl. Acad. Nauk. SSSR*, **65**, 465, 1949), who claims a positive result corresponding to an atmosphere of density 10^{-4} that of the earth. The horizontal refraction of such an atmosphere would be only $\frac{1}{4}''$ of arc. In particular, Lipski has refined the theoretical interpretation, allowing for the lunar aureole being only partially polarised.

While more experiments are required before the conclusions can be said to be in any sense definitive, it is interesting to note that an atmosphere of this density should be effective in stopping a meteor which on the earth would cause a normal visible shooting star. Shooting stars occur at about 70 miles height, where the atmospheric density is comparable with that near the lunar surface with the measured mass of the lunar atmosphere. In fact, some tentative observations of lunar meteor trails have already been reported (Haas, W. H., *Popular Astr.*, **55**, 266, 1947). The number of trails observed was consistent with their being lunar meteors, but inconsistent with their being terrestrial telescopic meteors. These observations may be said to give some confirmation of Lipski's conclusion that the moon is not a completely bare world.*

* Since the submission of the manuscript of this article, a paper by Lyot has appeared describing an attempt to measure the intensity of lunar twilight with the Pic-du-Midi coronagraph (*C.R Acad. Sci.*, *Paris*, **229**, 1277, Dec. 1949). The negative result is believed to preclude the existence of a lunar atmosphere of density $> 10^{-8}$ that of the Earth, in contradiction to Lipski's results.

THE SECOND SATELLITE OF NEPTUNE. In the hierachy of astronomers there is a select aristocracy of whom Keats' " watcher of the skies " is the eternal symbol—the discoverers of new members of the solar family. Few succeed in joining its ranks, but fewer still can claim the privilege of qualifying for membership twice within the space of a little more than a year. Gerard P. Kuiper, of the McDonald Observatories, has followed his discovery of the fifth satellite of Uranus (see Hunter, SCIENCE PROGRESS 36, 466, July 1948) by announcing the detection of a second satellite of Neptune (*Pub. Astr. Soc. Pacific,* 41, 175, Aug. 1949).

The discovery was made on photographs taken at the prime focus of the 82-inch telescope on May 1, 1949. The prime focus was chosen, as distant satellites were being sought, earlier photographs at the Cassegrain focus for close satellites having produced negative results. In fact, to obtain a large field, the object glass was stopped down to 66 inches (f/5). The satellite was magnitude 19·5 on discovery, and was about 180 seconds of arc distant from the planet. From further plates taken by Jose, it is hoped to obtain an orbit. At the present preliminary stage of reduction, a circular orbit with either retrograde or direct motion would represent the data almost equally satisfactorily. Provisional elements give the actual distance from the planet as between 8 and 9 million km., and an inclination to the ecliptic of only 5°. The satellite is thus moving in an orbit which is neither in the plane of Neptune's equator (which is inclined at about 30° to the ecliptic) nor in the plane of the orbit of the other satellite, Triton (inclination 136° to ecliptic, stellar magnitude 13, mean opposition distance 17" or approximately 400,000 km.) From the stellar magnitude, a diameter of 300 km., some one-sixteenth that of Triton, is estimated.

The system of Neptune provides some interesting problems in cosmogony. Bode's law is only one of the many numerical relations between planetary distances that have been proposed, but it is undoubtedly one of the simplest, and it is difficult to believe that it is entirely a coincidence. Indeed, a recent addition to the plethora of theories of the origin of the solar system, the accretion theory of von Weizäcker, actually leads to a law very similar to that of Bode. It is interesting to note that Neptune, apart from possessing a unique satellite system, also appears as an anomalous interloper in the scheme of planetary distances, the ninth term of the Bode-Titius law being 388 (on the scale Earth = 10) which corresponds closely to the mean distance of Pluto (390) rather than Neptune (301). Kuiper has recently approached the problem of relative planetary and satellite distances, not from the purely numerical

standpoint, but from considerations of orbital stability (*Astrophys. J.* **109**, 308, March 1949). He concludes that a satellite orbit is stable if

$$\mu/\Delta^3 \gg 1$$

where μ is the ratio of the mass of the primary to that of the sun, and Δ the satellite distance from the primary in units of the distance to the sun. In the case of the moon, this stability parameter is 100 ; for the least stable satellites known, the outer satellites of Jupiter, the parameter is 18, and no satellite is to be expected with a parameter less than 10. The stability parameter for the second satellite of Neptune is about 8000. Thus, in spite of the very great distance of this satellite from the primary comparable with the outer Saturnian satellites, in the Neptunian system distances of ten times this would still yield stable orbits. This analysis was undoubtedly the stimulus for wide-field photography of Neptune, and additional work is in progress at McDonald to cover the field of Neptune to these distances.

The accepted right and responsibility of giving a name to a newly-observed body may impose no mean burden on the discoverer, for he must stray to the possibly unfamiliar paths of mythology for his inspiration. In the case of Neptune's second satellite, the choice was not difficult ; since Neptune was attended by the Tritons and the Nereids, Kuiper has proposed the name Nereid for the new satellite. His choice for the fifth satellite of Uranus (*Pub. Astr. Soc. Pacific*, **61**, 129, 1949) seems to have caused greater difficulty, for the announcement was much delayed, and the final name, Miranda, arrived at by a devious literary route. The children of Uranus, the Titans, having been annexed by Saturn, Sir John Herschel named the four brighter satellites of Uranus Ariel, Umbriel, Titania and Oberon. Ariel appears in *The Tempest*, " an airy, tricksy spirit, changing shape at will to serve Prospero, his master " ; Miranda and her sister Dorinda were " daughters to Prospero that never saw Man." But Man has seen Miranda, and the discoverer of the sixth satellite of Uranus will find no difficulties of nomenclature, for Kuiper has presented him with a *fait accompli*.

PHYSICS. By F. A. VICK, O.B.E., Ph.D., F.Inst.P., The University, Manchester.

THE PHYSICS OF HEATING OF BUILDINGS.—**1.**—The necessity for fuel economy in recent years has stimulated in several countries more accurate and extensive studies of the factors involved in efficient heating of buildings (*see*, for example, *Post-War Building*

Studies, No. 19, 1945 ; the *Annual Reports* of the Building Research
Board, and of the N.P.L.). Recent work in the Laboratory of
Heating and Ventilation of the Technical University of Denmark
has now been published in a series of papers (*Trans. Danish Academy
of Technical Sciences*, No. 4, 1947), and since the journal is not widely
available in the country some account of the more physical aspects
of the work may be of interest.

The first paper, by F. C. Becker, is concerned with the factors
determining the nature of thermal fields in rooms, and the funda-
mental equations governing heat flow expressed in forms convenient
for practical use. The thermal conductivity equation becomes

$$R\frac{H}{A} = \Theta_m - \Theta_n \qquad . \qquad . \qquad . \qquad (1)$$

where R is a thermal resistance of unit area (thermal resistivity for
conduction processes is $1/K$, where K is the thermal conductivity
of a homogeneous material). H is the rate of flow of heat and is
measured in kilogram calories per hour. The area A is in square
metres. H/A is called " the density of heat flow." $\Theta_m - \Theta_n$ is the
corresponding temperature difference (degrees centigrade). The
same equation is extended to cover the transfer of heat by convec-
tion and radiation as well as conduction, with corresponding exten-
sions of the meaning of R. For conductivity through plane-parallel
walls large enough for boundary conditions to be ignored,

$$R_K = \frac{1}{K}d \qquad . \qquad . \qquad . \qquad (2)$$

where d is the wall thickness in metres. K is, strictly, dependent
on temperature and moisture content, but in practice it is usually
sufficiently accurate to use a mean value.

To extend equation (1) to radiation, a radiation resistivity * σ and
radiation resistance R_r are introduced. Then, by analogy with (2),

$$R_r = \frac{1}{C_r}\Theta_r \qquad . \qquad . \qquad . \qquad (3)$$

where Θ_r is a temperature factor with dimensions (degrees absolute)$^{-3}$.

$$\frac{1}{C_r} = \frac{1}{\sigma_m} + \frac{A_m}{A_n}\left(\frac{1}{\sigma_n} - \frac{1}{\sigma_o}\right) \qquad . \qquad . \qquad (4)$$

σ_m, σ_n and σ_o are the radiation resistivities of a hot body (surface
area A_m) radiating in the room, the surrounding walls (area A_n)

* The term " radiation resistivity " is introduced by analogy with thermal
resistivity in order to bring the general equations to the same form. In this
country ρ would be used instead of the σ used in the Danish papers.

and a full radiator respectively. $\sigma_o = 0.20$ (deg. Abs.)[4] (hours) (metres)^2(kg. cal.)$^{-1}$, and for surfaces usually encountered in buildings $1/\sigma_m$ and $1/\sigma_n$ are about 10 per cent. greater than $1/\sigma_o$ so that $(1/\sigma_n - 1/\sigma_o)$ is normally about 0.02. A_m/A_n is between 0 and 1, so that the second term of (4) is generally small relative to $1/\sigma_m$.

The temperature factor Θ_r is, approximately,

$$\Theta_r = 25\left(\frac{\Theta_{av} + 273}{100}\right)^{-3} \qquad . \qquad . \qquad . \qquad (5)$$

where $\Theta_{av} = (\Theta_m + \Theta_n)/2$ and Θ_m and Θ_n are the temperatures (deg. C.) of the radiating surface and the walls of the room. Θ_r varies between 1.23 and 0.74 as Θ_{av} varies from -5 to $50°$ C. For diffuse radiation, by analogy with equation (1)

$$R_r\frac{H_r}{A_m} = \Theta_m - \Theta_n \ . \qquad . \qquad . \qquad . \qquad (6)$$

Equation (6) also applies when the radiating surface is part of the wall of the room. If the rest of the wall, area A_n, is divided into homogeneous areas numbered $1 \ldots p \ldots q$, then the fraction ϕ_p of the diffuse radiation H_r striking the pth area, A_{np} of the wall is

$$\phi_p = \frac{A_{np} \cos \alpha_p \cos \beta_p}{l_p^2 \qquad \pi} \qquad . \qquad . \qquad . \qquad (7)$$

where l is the length of the line joining the centres of A_m and A_{np}, α_p is the angle between this line and the normal to H_m, and β_p is the corresponding angle for A_{np}. Then equation (6) becomes

$$R_{rp}\frac{H_{rp}}{A_m} = \Theta_m - \Theta_n \qquad . \qquad . \qquad . \qquad (8)$$

in which $R_{rp} = R_r/\phi_p$.

In general, we have an equation like (8) for each of the areas $1 \ldots p \ldots q$ receiving radiation from A_m, even if Θ_n is different for each of the areas.

For heat transmission by convection, there are two cases to be considered : (a) forced convection, due to winds, fans, etc., (b) natural convection. For case (a),

$$R_c = \frac{1}{5 + 3.4v} \qquad . \qquad . \qquad . \qquad (9a)$$

if the wind velocity v does not exceed 5 metres per sec. and

$$R_c = \frac{1}{6.6v^{0.75}} \qquad . \qquad . \qquad . \qquad (9b)$$

if v does exceed this value. It will be noted that if $v = 0$, $R_c = 1/5$. In the second case, (b),

$$R_c = C_c\Theta_c \qquad . \qquad . \qquad . \qquad . \qquad (10)$$

where C_c is a shape-factor and Θ_c a temperature factor. For vertical flat walls

$$\Theta_c = (\Theta_a - \Theta_s)^{-0\cdot25} . \qquad . \qquad . \qquad . \quad (11)$$

where Θ_a is the air temperature and Θ_s the temperature of the wall surface. Θ_a may be greater or less than Θ_s. For these walls, $C_c = 0\cdot45$. In practice R_c is given a maximum value of $0\cdot35$ (when Θ_a and Θ_s are nearly equal) to allow for movements of occupants of the room and other " uncontrollable " causes. For convection, then, the heat transfer equation is in the now familiar form

$$R_c\frac{H_c}{A} = \Theta_a - \Theta_s . \qquad . \qquad . \qquad . \quad (12)$$

Consider now the total heat transmission from an inner space I through a wall to an outer one E. Then

$$R_t\frac{H_t}{A} = \Theta_I - \Theta_E . \qquad . \qquad . \qquad . \quad (13)$$

where R_t is the sum of R_I, the thermal resistance for transfer from space I to the inner wall surfaces R_W the thermal resistance to passage through the wall and R_E for transfer from the outer surface to space E. The main problem is to determine R_I and R_E, which are functions of radiation and convection as well as of conduction.

Becker goes on to classify four different kinds of thermal fields in rooms. (a) *One-source thermal fields* are those in which the thermal fields are governed by one factor only, such as a room with uniform air temperature and perfectly reflecting walls. All thermal fields in solids are one-source, because the field at any point is governed only by the temperature at that point. (b) *Two-source fields*, e.g. a room with a uniform air temperature Θ_a, and walls having diffusely radiating surfaces all at the same temperature Θ_s. (c) *Three-source fields*, as (b), for example, if the wall surfaces are not at uniform temperatures, but part at Θ_{s1} and part at Θ_{s2}. (d) *Many-source fields*, as (c) but with several different wall temperatures, etc.

The measurement of temperature in a one-source field is independent of the shape and orientation of a thermometer, which may therefore be an ordinary fluid one. Such a thermometer, is, however, inadequate for the determination of room temperature in a two-source field, since the reading will depend somewhat on the size and shape of the thermometer, which will, in turn, affect R_c. For reproducible and comparable results it is thus necessary to standardise on a form of thermometer. In cases (c) and (d) the reading on a thermometer will depend not only on its size and shape but also on its orientation with respect to the walls.

Now consider a space I the thermal field of which is controlled by q sources numbered $1 \ldots p \ldots q$. Between any one of these thermal sources and an area A_m at temperature Θ_m a partial heat flow is maintained of magnitude H_p determined by $(\Theta_p - \Theta_m)$ and the corresponding thermal resistance. The object is now to substitute for all q partial flows a single quantity H_I from a single fictitious source with resultant temperature Θ_I and the flow having equivalent resistance R_I. Two methods may be applied, one based on physical considerations and one on analysis.

(i) Each source has a relative thermal weight of $1/R_p$, and the resultant temperature Θ_I is

$$\Theta_I = \left(\frac{\Theta_1}{R_1} + \frac{\Theta_2}{R_2} + \ldots + \frac{\Theta_q}{R_q} \right) R_I \qquad . \qquad . \quad (14)$$

in which $\qquad R_I = \dfrac{1}{\Sigma (1/R_p)} \qquad . \qquad . \qquad . \qquad . \quad (15)$

(ii) For each of the partial heat flows we have an equation of the form (cf., equation (1))

$$\frac{H_p}{A_m} = \frac{\Theta_p}{R_p} - \frac{\Theta_m}{R_p}.$$

When these are summed,

$$\frac{H_I}{A_m} = \sum \frac{\Theta_p}{R_p} - \sum \frac{1}{R_p} \Theta_m \qquad . \qquad . \quad (16)$$

or, from equation (14)

$$R_I \frac{H_I}{A_m} = \Theta_I - \Theta_m . \qquad . \qquad . \quad (17)$$

Θ_I so determined is not universally characteristic of the room, but is, in general, a directional quantity dependent on the area A_m chosen.

Measurements may be made by what are, in effect, *thermal fluxmeters*, in which the heat detector is maintained out of balance with the surrounding field. There are two main types. (A) The mean temperature of the apparatus is kept constant and measurement is made of the rate of heat loss H_m of the apparatus and of Θ_I relative to the apparatus. (B) The rate of heat supplied, H_m, is kept constant and measurements made of Θ_m of the apparatus as well as of Θ_I. The *Kata-thermometer* is an instrument of type (A), but it gives only one result at each place in a room without detecting directional changes.

. **2.**—The second paper, by N. F. Bisgaard, is concerned with the construction and use of directional thermometers. If these are

constructed with a flat face thermally sensitive and a back thermally insulated, the net flow, H_I, through the instrument is zero, so that $\Theta_I = \Theta_m$.

Two forms of directional thermometer are described. The first, and more elaborate, consists essentially of a thin rectangular piece of copper foil stuck over a slightly smaller hole in a rectangular piece of silk paper stretched on a frame of thin wood. The outside face of the copper foil is blackened, and the inner face is protected by several sheets of aluminium foil stretched in the frame and separated by air spaces. At the back of these is a brass plate containing an electrical heater, then several more aluminium foils, and finally a polished brass box which can contain water.

Copper-constantan thermocouples are used to determine the temperature of the copper foil and the difference between the temperature of the latter and of the brass disc. In use, the temperature of the heater is adjusted to be the same as that of the copper foil, in which case no heat is lost from the back of the latter, and the instrument is a directional thermometer. If the temperature of the copper foil face is less than that of the back of the apparatus, cold water is poured into the brass box at the rear. The second form of the instrument is simpler in construction, without the compensating heater.

Using the compensating form of directional thermometer, measurements were made in the anteroom of a dark room, with walls and ceiling at a known uniform temperature with the addition of a heated plate near one wall. The equations developed in Section 1 above were verified completely. In addition, correction curves and tables were determined for the simpler form of the instrument, in which the back of the detector plate is not completely insulated. The apparatus was then used to determine the effect of diffuse daylight, both through a window and reflected from the walls of the room, adding to the thermal sources in the room.

3.—The next paper, by Becker and Bisgaard, contains calculations of thermal fields for one-dimensional heat flows in walls under unsteady conditions, by a method of difference analysis which does not require the boundary conditions to be expressed as analytical functions. Several practical cases are considered, including compound walls. The alternative use of Heaviside's operational calculus is considered in the fourth paper, by Becker.

4.—The remaining four (shorter) papers deal with fields in which the temperatures vary approximately periodically with time, of which the most important example is the 24-hour cycle. Periodic variations in wind velocity are taken into consideration. One of

the results obtained shows the importance of the thermal capacity (specific heat) of the building materials, since walls may act as " heat accumulators " tending to reduce the heat loss by transmission during free cooling at night. This effect has a bearing on whether heat insulation should be applied to the interior or exterior of an outside wall. The final paper contains an actual example of the calculation of the heat loss from a typical room with a 24-hour temperature cycle.

5.—It is hoped that the summary given above will indicate how the fundamental heat equations are transformed so as to be immediately useful to the practical heating engineer, and how the interpretation of experimental results is simplified by the use of special differential thermometers.

The present author is much indebted to the Danish Press Attaché in London, who kindly arranged for him to receive a copy of the journal containing the papers described.

GENERAL AND PHYSICAL CHEMISTRY. By J. W. Smith, D.Sc., Ph.D., F.R.I.C., Bedford College for Women, London.

RADIATION CHEMISTRY.—Whilst many reactions which are brought about under irradiation with α-particles or β-rays have been known and studied for many years, this subject, lying on the fringe of both photochemistry and of nuclear chemistry, has received a new impetus in recent years through the development of the latter subject. New forms of apparatus, such as large cyclotrons, devised in connection with the study of nuclear reactions, have proved of inestimable value in studying the chemical effects of the primary particles. Nuclear fission itself not only produces in abundance some of the high energy particles which were previously known to effect radiochemical reactions, but it also yields types of high-velocity particles, such as high-energy β- and γ-rays and fission particles, which are not obtainable otherwise. As their effects, direct and indirect, in causing chemical reaction are almost inseparable from the particles themselves, and are intimately linked with their effects upon living organisms, the processes induced by them have become of vital interest to biologists, as well as to physicists and chemists.

It was opportune, therefore, that a symposium held at the University of Notre Dame, Indiana, in June 1947 was devoted very largely to radiation chemistry, and surveys of various aspects of the subject were given by Lind, Steacie, Hirschfelder, Rosenblum, Allen, Dainton, Burton, and others, who have been most intimately concerned with its development.

Although in a sense radiation chemistry can be regarded as a branch of photochemistry, there are a number of essential differences between the two.   It is found that, when a beam of ionising radiation is passed through matter, only about half the energy is expended in the production of ions, the remainder being used in the formation of excited molecules.   There has been considerable difference of opinion as to whether it is the ions or the excited molecules which play the more important rôle in causing reaction.   Initially the tendency was to concentrate on the ions and to neglect the effect of the unionised excited molecules, but the present view is that both play significant parts.   The processes involved are therefore much more complex than in photochemical reactions, and the quantitative aspects of the subject are more difficult to elucidate than, for instance, the quantum efficiency of a photochemical reaction.   Thus, for example, it is possible for the number of ion pairs formed in the irradiation, the usual method of expressing the radiation absorbed, to be only a rough measure of the number of molecules which are excited and cause reaction.

Whereas in a photochemical reaction whole quanta of radiation are generally absorbed, and the primary process may be dependent on the wavelength of the incident radiation, evidence regarding its nature being obtained from the form of the absorption spectrum in various spectral regions, in radiation chemistry the energy of the particle is gradually decreased during its passage through matter. Hence the chemical effects are generally dependent only upon the total amount of energy absorbed and not on the energy of the individual particles.   One particular high-energy particle may therefore give molecules of several different excitation states as well as different ion species from each of the substances present in the absorbing medium.   These particles, and the electrons which are detached in the primary ionisation process, may then enter into secondary reactions and ionisation processes, with the production of yet further particle species.

The fundamental processes normally involved in these reactions have been enumerated by Hirschfelder (*J. Phys. Coll. Chem.*, 1948, **52**, 447) as

1. The primary and secondary ionisations.
2. The excitation without ionisation.
3. The electron attachments and negative ion formation.
4. The simple reactions between ions and neutral molecules.
5. The formation of clusters, if any.
6. The neutralisation of the ions to form atoms and free radicals.
7. The subsequent fate of the free radicals and ions.

The probability of ionisation occurring when a charged particle traverses a molecule is greatest for heavy and slow-moving particles. As an α-particle in air forms about 25,000 ion pairs per cm. of its path, it must ionise every molecule which comes within 1 Å. of it. In spite of this fact, about four-fifths of the total ionisation is produced by secondary electrons. This accounts for the fact that, as a rule, α-, β-, and γ-rays all have the same chemical action, since they all produce secondary ionisation which produces most of the ion pairs, and the effects of the radiations are generally measurable in terms of the total irradiation received. The exceptions to this general rule can be attributed to the fact that fast electrons excite or ionise only 1 per cent. or less of the molecules which they traverse, so the primary ions or excited molecules produced are much more widespread than in the case of α-particles, deuterons, or slow electrons, which form " hot " spots, i.e. regions of very intense ionisation, within a narrow zone along the track of the particle. Particularly in the liquid or solid phase this may lead to partial recombination or abnormal reaction of the active particles before they can diffuse into the main body of the medium.

It is obviously of great importance to know what particles are produced in these processes. So far as the ions present are concerned, mass spectroscopy yields a great deal of information, and can be used to determine appearance potentials, and to distinguish between primary and secondary products. With gases at very low pressures it is possible by this means to measure the relative abundance of both the positive and negative ions ; this relative abundance is the same as if these ions were formed by any high-voltage ionising source such as the secondary radiation from α-, β-, or γ-rays. At higher pressures the mass spectrograph gives indications of the particles formed when ions react with neutral molecules, as in the reaction $H_2 + H_2^+ \rightarrow H_3^+ + H$.

Unfortunately, however, there is no means of obtaining the equivalent information with regard to the excited molecules. As in radiochemical reactions in gases excitation and ionisation occur in about equal amounts, excited molecules might be expected to play an important part in these processes. The evidence, in fact, now suggests that they are of more importance in the reactions than the ions. In the case of hydrogen, excited molecules are known to dissociate frequently into atoms, but there is no way of knowing the properties of more complex excited molecules, as neither spectroscopic nor mass spectroscopic methods can be applied to their study. For the same reason there is no knowledge of the number of excited molecules which are formed per ion pair.

For the case of the decomposition of ammonia by α-rays, Miss Smith and Essex (*J. Chem. Phys.*, 1938, **6**, 188) separated the reactions due to excited molecules from those due to ionisation by carrying out the irradiation between the plates of a condenser. The values which they obtained for the ion yields in the absence and presence of electric fields at 30° C and 100° C. were as follows :

	30° C.	100° C.
No field	1·37	2·42
Half saturation field . .	1·17	2·06
Full saturation field . .	1·08	2·01

These results were interpreted by supposing that in a field sufficiently strong to produce half saturation the ions are neutralised on the plates without decomposition. If this is correct, of the ion yields at 30° and 100°, 0·40 and 0·72, respectively, must be due to the recombination of ions, whilst the yields due to other mechanisms are 0·97 and 1·70, respectively. At each temperature, therefore, only about 30 per cent. of the total reaction occurs through the formation of ions.

At the time when ions were regarded as being of more importance than neutral molecules, it was found that the mobilities of these ions were in many cases smaller than would be expected on the basis of the kinetic theory. This was interpreted on the basis of the " cluster theory," in which neutral molecules were supposed to be held to the ion by polarisation forces. Reaction was then regarded as occurring on neutralisation of the charge and involving all the molecules present in the cluster. This accounted for relatively high values of the ratio of molecules reacted to ion pairs formed (M/N). Lind, who originated this theory some twenty years ago, has recently enumerated some of the indirect evidence in support of this theory (*J. Phys. Coll. Chem.*, 1948, **52**, 440). This is

(1) Exclusive oxidation when oxygen is present. The affinity of oxygen for electrons is supposed to favour oxidation reactions upon the recombination of positive and negative ions around which oxygen molecules are clustered.

(2) Smaller values of M/N are obtained in the absence of oxygen.

(3) Occlusion of small amounts of inert gas in the solid product formed by the polymerisation of acetylene by α-rays. This is liberated easily on gently heating the vessel wall.

(4) Carbon dioxide alone is not decomposed by α-rays, but when a suitable acceptor for the CO_2^+ ion, for instance hydrogen or

methane, is introduced, additional reaction occurs at a rate proportional to both the CO_2^+ and CH_4^+ or H_2^+ ions.

(5) In any mixture of reactants the rate is proportional to the sum of both ions and not to one species alone, as might be assumed if a radical of one kind were instrumental.

(6) Reactions such as the polymerisation of acetylene show no characteristics of chain mechanism, but are associated with a high yield per ion pair.

The case of the polymerisation of acetylene will be discussed later, but, generally speaking, modern views are against the cluster theory, the low mobility of the ions being attributed to the drag associated with polarisation forces without actual cluster formation. A classical example of a reaction the course of which was explained very simply by the cluster mechanism was the synthesis of ammonia in an electric discharge. Brewer and Westhaver (*J. Phys. Chem.*, 1930, **34**, 153) suggested two alternative mechanisms for this reaction ;

(a)
$$N_2^+ + H_2 \rightarrow N_2H_2^+$$
$$N_2H_2^+ + \varepsilon \rightarrow 2\,NH$$
$$NH + H_2 \rightarrow NH_3$$

(b)
$$N_2^+ + 3\,H_2 \rightarrow N_2H_6^+$$
$$N_2H_6^+ + \varepsilon \rightarrow 2\,NH_3$$
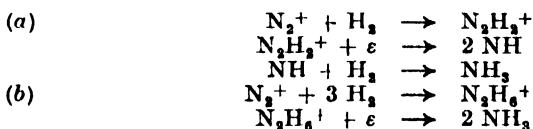
The first mechanism involves only normal two-body collision, but the investigators preferred the second mechanism, which required cluster formation, as four-body collisions are extremely improbable.

The present views with regard to radiation reactions can be best illustrated with reference to a few selected reactions from amongst the many which have been studied. The first tendency to interpret them on the assumption that the ions initially formed undergo simple reactions leading to the formation of atoms and radicals, which are then involved in normal processes such as are encountered in photochemical reactions, arose out of what would superficially, at any rate, appear to be the simplest of all these reactions, namely the conversion of para-hydrogen to ortho-hydrogen under the action of α-particles. The ionic yield (800–1000) is in this case much too great to be explained by any clustering mechanism, and Capron (*Ann. Soc. sci. Bruxelles*, 1935, **B55**, 222) found that the rate of conversion was proportional both to the concentration of parahydrogen and to the intensity of the irradiation. Reaction chains must therefore be formed, and, furthermore, no mutual termination of reaction chains can occur, say by combination of atoms or ions in the gas phase. As no reaction occurred at $-187°$ C., Capron concluded that hydrogen atoms rather than protons were the effective

agents and that the action involved could be represented

$$H + H_2(p) \rightleftharpoons H_2(o) + H$$
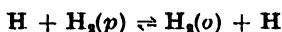
In reviewing these results, Eyring, Hirschfelder, and Taylor (*J. Chem. Phys.*, 1936, **4**, 479) concluded that the chain-breaking reaction was the removal of the atomic hydrogen on the vessel walls, and, assuming this process to be perfectly efficient, they found that the results could be accounted for if six hydrogen atoms were formed per 33 ev. of α-particle energy absorbed, *i.e.* six hydrogen atoms per ion pair formed. Such a state of affairs could be achieved if the 33 ev. is assumed to be capable of ionising one molecule and of activating another molecule to the $^3\Sigma$ state, from which it dissociates into two atoms. Their picture of the processes involved was therefore

$$
\begin{array}{llll}
& H_2 + \alpha & \longrightarrow & H_2{}^* + \alpha & \longrightarrow & 2H + \alpha & \text{(Excitation)} \\
\text{or} & H_2 + \alpha & \longrightarrow & H_2{}^+ + \varepsilon + \alpha & & \text{(Ionisation)} \\
& H_2{}^+ + H_2 & \longrightarrow & H_3{}^+ + H & & \\
& H_3{}^+ + \varepsilon & \longrightarrow & H_2{}^* + H & & \\
\text{or} & H_3{}^+ + \varepsilon & \longrightarrow & 3H & &
\end{array}
$$
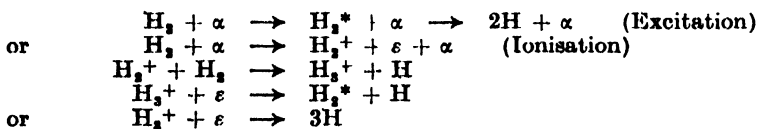
followed by the interaction of the hydrogen atoms with hydrogen molecules, as suggested by Capron. On this basis the yield is four hydrogen atoms per ion pair for those molecules which are dissociated by the ionic mechanism and two atoms per ion pair for the hydrogen atoms produced by dissociation without ionisation.

In pursuance of this conception, Eyring, Hirschfelder, and Taylor (*ibid.*, p. 570) suggested that in bromine vapour, owing to the possibility of the $Br_2{}^+$ ion dissociating into Br^+ and Br, about six bromine atoms would be produced per ion pair in the process which involves initial ionisation. The total yield of atoms will be greater than this owing to the dissociation into atoms without ionisation. Similarly they inferred that in the dissociation of hydrogen bromide between two and three hydrogen atoms will be formed per ion pair by the ionic mechanism. On this basis, combined with a consideration of the reactions which may occur between the excited particles and normal molecules they derived expressions which were in accord with the observations of Lind and Livingstone for this reaction.

One of the most fully investigated reactions has been the polymerisation of acetylene under the influence of α-particles to yield a solid product which, although often called Cuprene, has been found to differ from the products formed by catalytic polymerisation or in a corona discharge, and for which the name " Alprene " has been suggested (Watson, *J. Phys. Coll. Chem.*, 1948, **52**, 470). Under α-irradiation about 20 molecules of acetylene polymerise per ion pair formed and this yield is independent of the conditions over wide

ranges. The rate of reaction is proportional to the gas pressure and to the intensity of the irradiation. The addition of inert gases (helium, neon, nitrogen, argon, krypton, or xenon) increases the rate of polymerisation and the reaction rate seems to depend on the total ionisation and not on the ionisation of acetylene alone. It was in respect of this reaction that the clustering hypothesis was most strongly held, it being supposed that each ion became surrounded by about 20 acetylene molecules which reacted upon neutralisation to give one polymeric molecule (Lind and Bardwell, *Science*, 1926, **62**, 593).

$$C_2H_2 + \alpha \longrightarrow C_2H_2^+ + \epsilon + \alpha$$
$$C_2H_2^+ + 19\ C_2H_2 \longrightarrow (C_2H_2)_{20}^+$$
$$(C_2H_2)_{20}^+ + \epsilon \longrightarrow (C_2H_2)_{20}$$
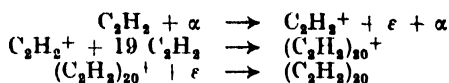
The product is insoluble and hence molecular weight determinations are impossible, whilst Watson's electron microscopic studies indicated that the particles obtained comprise more than 19 or 20 acetylene units, but otherwise neither confirmed nor disproved the cluster mechanism.

In point of fact, however, this strained the cluster concept rather severely, as it is difficult to picture sufficiently strong polarisation forces as to hold together such a large cluster. It is now known that the polymerisation of unsaturated hydrocarbons can be sensitised by free radicals, so there is no objection to a mechanism involving stepwise addition, whilst chain transfer reactions may occur as with other polymerisation reactions. It was pointed out by Garrison (*J. Chem. Phys.*, 1947, **15**, 78) that in an ionic or Friedel-Crafts polymerisation aluminium chloride, boron trifluoride, protons, or other strong acids [in the Lewis sense] lower the activation energy by combining with the ionic activated state in which two electrons of the unsaturated bond occupy the same orbital. Hence he suggested that in the polymerisation of acetylene by ionising radiations the $C_2H_2^+$ ions may act as the acid catalyst by combining with the negative carbon atom of the ionic resonance form of acetylene according to the equation

$$\overset{+}{H:C}::\overset{..}{C}:H + H:\overset{+}{C}::\overset{.}{C}:H \longrightarrow H:\overset{+}{C}::C::\overset{H}{\underset{\overset{..}{H}}{C}}:\overset{.}{C}:H$$
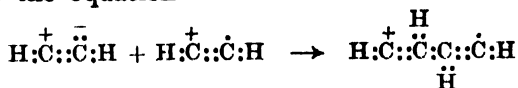
Polymer would be formed by further reaction of the positively charged carbon. The presence of an unshared electron in the $C_2H_2^+$ ion would make a polymerisation via a free radical mechanism also possible, in which case reaction occurs according to the equation

$$H:\overset{.}{C}::\overset{.}{C}:H + H:\overset{.}{C}::\overset{+}{C}:H \longrightarrow H:\overset{.}{C}::C:\overset{H}{\underset{H}{\overset{+}{C}}}:\overset{.}{C}:H$$
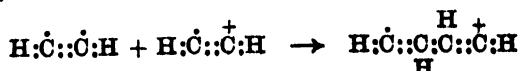
It has been observed by Rosenblum (*J. Phys. Coll. Chem.*, 1948, **52**, 474) that, in addition to the high molecular weight polymer, benzene is also a product of the radiochemical polymerisation, of acetylene. Under the conditions studied by him about one-fifth of the reacting acetylene was used in benzene formation. He pointed out that, on the cluster theory, this would imply that there must be two sizes of cluster, one of three molecules and the other of much larger size, the former being the more numerous, a supposition entirely at variance with the cluster theory. Owing to its striking similarity to the photochemical reaction, Rosenblum prefers to explain the radiochemical reaction as proceeding through successive bimolecular reactions between a normal acetylene molecule and an excited molecule of acetylene or polymer, thus

$$C_2H_2{}^* \xrightarrow{C_2H_2} (C_2H_2)_2{}^* \xrightarrow{C_2H_2} (C_2H_2)_3{}^*$$
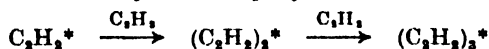
where $(C_2H_2)_2{}^*$ and $(C_2H_2)_3{}^*$ stand for excited polymer molecules presumed to be linear in character. At the trimer stage two reactions may occur, either further polymerisation to form $(C_2H_2)_4{}^*$, etc., or cyclisation to form benzene

$$(C_2H_2)_3{}^* \rightarrow C_6H_6$$

He showed that this last reaction is possible thermochemically.

Whatever may prove to be the mechanism of this reaction, whether it may prove to occur through the ions or excited molecules or both, the effects of the inert gas molecules must be explained. Their effects may be due to their ionising or exciting an acetylene molecule on collision, or to their entering initially into the composition of the polymeric ions and then being eliminated again on neutralisation.

In liquid media the position with regard to radiochemical reactions is even more complex. The decomposition of water by α-particles was first observed in about 1905, and during subsequent years various investigations seemed to indicate that the reaction was a simple radiation decomposition with production of hydrogen and oxygen, but with some of the oxygen remaining as hydrogen peroxide. The yield was about two molecules of hydrogen per 100 ev. of radiation energy absorbed.

The effect of X-rays had been regarded as similar, but in 1929 Risse (*Z. physikal. Chem.*, 1929, **140**, 133) observed that pure water was not decomposed by X-rays, and that the formation of hydrogen peroxide usually observed under such conditions arose from reaction between dissolved oxygen and the water. In following up this observation, Fricke and his co-workers (*J. Chem. Phys.*, 1938, **6**, 229) found that the gas evolved from irradiated water comprised hydrogen

and carbon dioxide, and must have arisen from the decomposition of organic matter in the water. Purification of the water to remove organic matter reduced the yield of gas, but this never became zero, and Fricke suggested that irradiation with X-rays was the best method of purifying water.

On the other hand, X-rays oxidise or reduce inorganic compounds in aqueous solution, and decompose organic compounds with evolution of hydrogen and sometimes of carbon dioxide ; in each case one molecule reacts for approximately every 100 ev. absorbed. The evidence indicates that the radiation activates the water to a form of sufficiently long life to permit it to encounter and react with solute molecules before this energy is dissipated, even when the solution is very dilute. As no other active species would have a sufficiently long life for this purpose, it is now believed that the water is decomposed under irradiation into the free radicals H and OH. The formation of these radicals would be expected as the natural sequel to ionisation of the water by the radiation

$$H_2O \longrightarrow H_2O^+ + \varepsilon$$
$$H_2O + \varepsilon \longrightarrow H + OH'$$
$$H_2O^+ + H_2O \longrightarrow H_3O^+ + OH$$
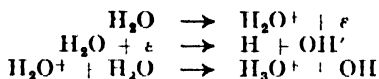
Similarly, excited water molecules might be expected to dissociate directly into H and OH radicals.

In the absence of a solute with which they can react, these radicals will disappear by reaction with one another to re-form water or to form hydrogen and hydrogen peroxide. The reason why the latter products are obtained in appreciable quantities when irradiation is carried out with α-particles, but not when X-rays are passed through pure water, is to be sought in the reactions in which the hydrogen and hydrogen peroxide are decomposed again, probably

$$OH + H_2 \longrightarrow H_2O + H$$
and $$H + H_2O_2 \longrightarrow H_2O + OH$$
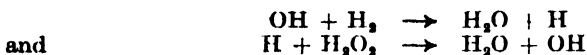
It would therefore be expected that a steady state concentration of the products would be obtained. This was confirmed by Allen and Ghormley (*cf.* Allen, *J. Phys. Coll. Chem.*, 1948, **52**, 479) who showed that with 1 mev. electrons, or with X-rays, the equilibrium concentrations of the products were very low, and increased with increasing intensity of the irradiation. The difference between the effects of X-rays and of α-particles is therefore attributable to the greater ionising power of the latter, with the result that the amount of hydrogen produced exceeds its solubility at atmospheric pressure, and the gas is evolved. The evolution of oxygen is attributable to the decomposition of the hydrogen peroxide. With deuteron bombardment the state of affairs is intermediate, the steady state

corresponding to a hydrogen pressure of only slightly above one
atmosphere.

The presence of solutes complicates this picture very considerably,
as some can be oxidised, some reduced, and even those solutes which
appear to be unaffected, like traces of potassium bromide, hydro-
chloric acid, nitric acid, and even dissolved Pyrex glass, can still
increase the steady state hydrogen pressure. This latter effect is
attributed to inhibition of the back reaction by the solute. It has
been pointed out by Allen that the back reaction is a chain process,
closely resembling the hydrogen-chlorine reaction, but with OH
radicals taking the place of chlorine atoms and hydrogen peroxide
molecules that of chlorine molecules. The effect of impurities, there-
fore, resembles closely that of inhibitors in the hydrogen-chlorine
reaction, and is most probably due to chain-breaking reactions. He
suggests, for instance, that the dissolved glass may react with OH
radicals to form some sort of persilicic acid radical which is incapable
of reacting with hydrogen molecules. In the presence of nitric acid,
during short irradiations practically only hydrogen is evolved, but
after cessation of the irradiation oxygen continues to be evolved
until the final gas is exactly one-third oxygen. He considers that
the OH radicals become tied up with the nitric acid to produce some
form of pernitric acid which is thermally unstable but, unlike
hydrogen peroxide, will not combine with hydrogen under irradiation.
With long periods of irradiation a steady state is reached when
oxygen is produced from the decomposition of the pernitric acid at
the same rate as it combines with hydrogen under the influence of
the radiation.

Allen further suggests that, in the presence of bromide or iodide,
interaction occurs between the hydroxyl radicals and the halide ion,
leading to a sequence of processes of the type

$$H_2O \rightarrow H + OH$$
$$OH + Br' \rightarrow Br + OH'$$
$$Br + H \rightarrow H^+ + Br' \quad or \begin{cases} Br + Br \rightarrow Br_2 \\ Br_2 + H \rightarrow Br + H^+ + Br' \end{cases}$$
$$OH' + H^+ \rightarrow H_2O$$
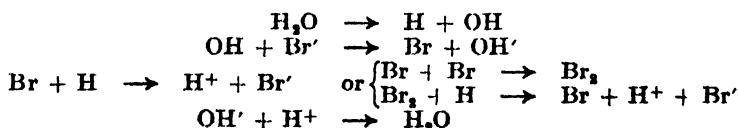
The sum of these processes is zero, and hence, since the halide ions
increase the equilibrium concentrations of the decomposition pro-
ducts over those for pure water, he infers that they must be produced
in some way other than by interaction of radicals. He attributes the
effect to the small regions of high ionisation (hot spots) at the end of
each electron track, where the radicals formed will react with one
another before they have a chance to interact with bromide ions or
bromine atoms. It is difficult to see on this theory, however, why

the increased equilibrium concentrations are attained in the presence of the halide, as similar hot spots will be present whether it is present or not.

An alternative mechanism proposed by Dainton (*N.R.C. of Canada, Division of Atomic Energy, Research Report* CRC304, 1946) was that the bromine atoms react not only with the free hydrogen atoms to form bromide ions, but also with the hydroxyl radicals to form hypobromous acid, which in turn could react with further hydroxyl radicals to form hydrogen peroxide

$$Br + OH \longrightarrow HOBr$$
$$HOBr + OH \longrightarrow H_2O_2 + Br$$
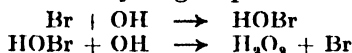
As the hydroxyl radicals are used up in this way the equivalent number of hydrogen atoms must recombine to form hydrogen molecules. This view certainly does appear to explain the increased liberation of hydrogen and hydrogen peroxide quite simply ; Allen regards this process as possible, but its introduction unnecessary.

Oxidation and reduction reactions in aqueous solution are comparatively easily explained as being brought about by the hydrogen and hydroxyl radicals, *e.g.*

$$Fe^{+++}, aq. + H \longrightarrow Fe^{++}, aq. + H^+, aq.$$
$$Fe^{++}, aq. + OH \longrightarrow Fe^{+++}, aq. + OH'$$
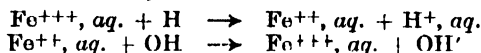
although oxidation by hydrogen peroxide also occurs in many instances. As normally both the oxidation and reduction process can be brought about under the action of the radicals, an equilibrium state will be attained in such systems in which the ratio of the oxidised to the reduced form depends on the redox potential, the type of radiation involved, the hydrogen peroxide concentration, etc.

The radiation-induced reactions of organic compounds in aqueous solutions appear also to result from the action of hydrogen atoms and hydroxyl radicals. For instance, in the γ-ray induced polymerisation of acrylonitrile in aqueous solution, studied by Dainton (*J. Phys. Coll. Chem.*, 1948, **52**, 490) the reaction rate is independent of the dose rate and is of second order with respect to the solute concentration. This can be accounted for only by some reaction scheme of the form

$$H \text{ or } OH + m_1 \longrightarrow m_1^* \quad \text{(Initiation of chains)}$$
$$m_j^* + m_1 \longrightarrow m_{j+1}^* \quad \text{(Propagation of chains)}$$
$$m_j^* + H \text{ or } OH \longrightarrow m_j \quad \text{(Termination of chains)}$$
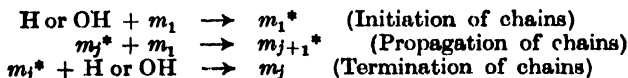
where m_1 and m_j refer to the monomeric form and a polymer comprising j units, respectively.

The effects of radiation on liquid organic compounds and on solutions in organic solvents have been much less fully investigated, and a generalised summary is at present unwarranted. Again, however, the products formed and the reaction kinetics are compatible

with the view that the processes operate through the formation of ions and free radicals, the latter being produced either by the detachment of a hydrogen atom or by rupture of the weakest carbon-carbon linkage.

BIOCHEMISTRY. By C. LONG, M.A., B.Sc., D.Phil., Department of Biological Chemistry, University of Aberdeen.

RECENT STUDIES ON PHOSPHOLIPINS

THE group of compounds known collectively as phospholipins, phospholipides or phosphatides, is composed of substances occurring in biological materials which possess both phosphate and fatty acid radicals in their chemical structures. For many years it was believed that this group included only a small number of closely related chemical individuals having very similar physical properties. Recently, however, several new types of phospholipin have been isolated, so that at present they comprise a very diverse group having widely different physical properties and chemical structures. Moreover, there is every indication that their numbers will continue to increase, for except in a very few cases, it has not been possible to account for the total phosphorus in a sample of crude phospholipin in terms of compounds of known constitution.

The widespread occurrence of phospholipins in cell protoplasm has been well established for many years and is indeed one of the main reasons for attaching such importance to the study of these substances. During recent years, several workers have been active in studying the metabolism of the phospholipins both in the intact animal and in surviving tissue preparations ; these investigations have been especially suited to and aided by the use of the now readily available radioactive phosphorus, P^{32}. In spite of the progress which has been made in this direction, the physiological rôle of these compounds is still by no means completely understood. There is little doubt, however, that when a more distinct picture of the part played by the phospholipins in intermediary metabolism becomes available, it will be found to depend largely upon a sure knowledge of the chemical nature of these substances and of the action of enzymes upon them. During the last ten years, much progress has been made in both these fundamental fields of study, and the main purpose of this review will be to record some of these advances.

THE CHEMICAL NATURE OF THE PHOSPHOLIPINS

Lecithin.—The lecithin portion of a crude phospholipin preparation may be taken as that part which contains the *whole* of its

nitrogen in the form of choline. Although the existence of lecithins has now been recognised for over a century, it has only recently become realised that ignorance of their ultimate chemical structure still prevails. For more than fifty years it had become customary to accept the existence in nature of both α- and β-lecithins (I and II respectively, derived from mixed component fatty acids represented by R.COOH).

$$CH_2O.CO.R$$
$$|$$
$$CHO.CO.R$$
$$|$$
$$CH_2O.\overset{-}{P}O_2.OCH_2CH_2\overset{+}{N}(CH_3)_3$$
(I)

$$CH_2O.CO.R$$
$$|$$
$$CHO.\overset{-}{P}O_2.OCH_2CH_2\overset{+}{N}(CH_3)_3$$
$$|$$
$$CH_2O.CO.R$$
(II)
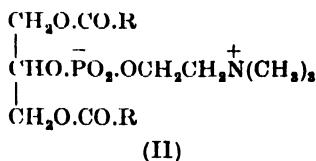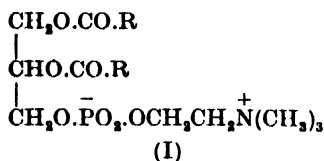
The main evidence for these configurations was the identification of both α- and β-glycerophosphates in an acid or alkaline hydrolysate of natural lecithin. Recent studies by Folch (*J. biol. Chem.*, 1942, **146**, 31) and by Baer and Kates (*J. biol. Chem.*, 1948, **175**, 79), however, have shown that this evidence is not valid. Thus, Folch has observed that when several different phosphoglycerides were vigorously hydrolysed by boiling with concentrated mineral acid, in each case 73 per cent. of the resulting glycerophosphate was found to exist in the α-form and 27 per cent. in the β-form. Moreover, when pure α- or β-glycerophosphoric acid was subject to the same treatment, a mixture of α- and β-forms in a similar ratio was obtained. The work of Baer and Kates has yielded further information regarding this isomerisation, for they have shown that hydrolysis of pure synthetic L-α-glycerophosphorylcholine under the mildest possible conditions, using dilute acid or alkali at body temperature, gave rise not only to the expected L-α-glycerophosphate but also to appreciable amounts of racemic α-glycerophosphate and of β-glycerophosphate. It is inferred from these studies that under the conditions of acid or alkaline hydrolysis, a reversible interconversion between α- and β-glycerophosphates is readily established, so that hydrolysis of either α- or β-lecithin would give rise to mixed glycerophosphates. Earlier results based on hydrolytic procedures are not entirely worthless, however, for, since on theoretical grounds only α-lecithin can be hydrolysed to an optically-active α-glycerophosphate, the isolation of this latter substance from a lecithin hydrolysate must be accepted as clear evidence for the existence in nature of the α-form. β-Lecithin, on the other hand, would normally give rise to β-glycerophosphate, which by isomerisation could yield only the racemic form of α-glycerophosphate. At the present time there is insufficient evidence to decide whether or not β-lecithins

also exist naturally. Before this can be proved, it will be necessary to remove the fatty acid radicals from natural lecithins by methods which exclude the possibility of $\alpha\beta$ interconversion. It should be stressed here that this uncertainty regarding the true configuration of the lecithins applies also to the other phosphoglycerides which will be referred to later.

Turning now to a consideration of the nature of the component fatty acids of the lecithins, it should be pointed out that earlier studies, which have been summarised by Levene and Rolf (*Physiol. Rev.*, 1921, **1**, 327), indicated that, when lecithins from different sources were hydrolysed, approximately one saturated and one unsaturated fatty acid per molecule could be identified. During the past thirty years this finding has been repeatedly confirmed. Lately, however, the preparation from two widely different sources of a lecithin containing no unsaturated fatty acid components, namely dipalmityl-lecithin (hydrolecithin), has been reported. Lesuk & Anderson (*J. biol. Chem.*, 1941, **139**, 457) and Thannhäuser *et al.* (*J. biol. Chem.*, 1946, **166**, 669 ; 1948, **172**, 135) have isolated this substance from the larvæ of the tapeworm *Cysticercus fasciolaris* and from a number of ox-tissues, respectively. Whether dipalmityl-lecithin has any special significance in metabolism is not yet known, but the fact that its existence remained undiscovered until so recently is readily explained. One of the initial stages in the fractionation of phospholipins is the extraction of lecithins and kephalins into ethereal solution, a process which leaves sphingomyelin undissolved. The absence of unsaturated fatty acid radicals from dipalmityl-lecithin, however, renders this substance insoluble in ether, so that it naturally becomes associated with the sphingomyelin fraction. It was from this source that, with considerable difficulty, Thannhäuser and associates were able to isolate it.

It was earlier pointed out that the naturally-occurring lecithins were characterised by the presence of bound choline in their molecules. Considerable interest therefore is attached to the fact that a lecithin analogue containing arsenocholine in place of choline has been prepared biosynthetically. This arsenic-containing phospholipin has been isolated by Welch and Landau (*J. biol. Chem.*, 1942, **144**, 581) from the carcasses of experimental animals fed on a diet containing arsenocholine chloride ($HOCH_2CH_2\overset{+}{A}s(CH_3)_3\overset{-}{Cl}$). This particular observation is of some significance for it provided one of the earliest pieces of evidence for the view that lecithins were synthesised from choline derived directly from the diet.

Phosphatidic Acids.—Perhaps the most striking advance in the

field of phospholipin chemistry of recent years has been the discovery of several new phosphatidic acids. The first of these substances was isolated from cabbage leaves more than twenty years ago by Chibnall and Channon (*Biochem. J.*, 1927, **21**, 233, 1112). Structurally, a phosphatidic acid is a phospholipin containing no basic radical. Thus a lecithin molecule could lose its choline group and so form the corresponding diglyceridephosphoric acid ; this was the type of phosphatidic acid isolated by Chibnall and Channon. Another, though slightly more complex, type of phosphatidic acid would be obtained by replacing the choline portion of lecithin by a non-basic group. As a result of the absence of a basic group, phosphatidic acids are strongly acidic and occur in biological materials as sodium, potassium, calcium or magnesium salts. In the case of the cabbage-leaf product, the calcium salt was isolated. This occurrence in the form of salts is quite the most characteristic property of the phosphatidic acids.

The new phosphatidic acids have generally been isolated from the " kephalin " fraction of crude phospholipins, *i.e.* the fraction soluble in ether but practically insoluble in ethanol. In this connection it should be mentioned that for many years the nitrogen of kephalin has been known to exist exclusively in the form of amino-nitrogen. Parnas (*Biochem. Z.*, 1909, **22**, 411) was the first to suggest that all the kephalin-N was present as ethanolamine. In the years that followed, the claim was supported by other workers and gradually came to be accepted. It should be noted, however, that during this period McArthur (*J. Am. Chem. Soc.*, 1914, **36**, 2397) did not support this view, but maintained instead that at least a part of the nitrogen was present as aminoacid-N. His evidence was based on the ability of kephalin hydrolysates to dissolve cupric hydroxide giving blue solutions, a property shared by all amino-acids, but not possessed by other amino compounds.

In 1941, the presence of the hydroxyaminoacid serine in the kephalin fraction of brain was shown independently by Folch and Schneider (*J. biol. Chem.*, **137**, 51) in the United States and by Schuwirth (*Z. physiol. Chem.*, **270**, 1 ; also 1942, **277**, 87) in Germany. About this time too, Chargaff, Ziff and Rittenberg (*J. biol. Chem.*, 1941, **138**, 439 ; 1942, **144**, 343) had arrived at a similar conclusion. In further papers, Folch (*J. biol. Chem.*, 1942, **146**, 35 ; 1948, **174**, 439) has shown conclusively that the serine moiety is esterified through its hydroxyl group with the phosphoric acid portion of the molecule. The complete molecule is designated *phosphatidyl serine* and appears to constitute between 40 and 70 per cent. of the kephalin fraction of ox-brain. Part of

the remainder has been identified as *phosphatidyl ethanolamine*, the compound which had earlier been assumed to represent the whole fraction. The presence of phosphatidyl serine in the kephalin fraction of other tissues has been shown by Artom (*J. biol. Chem.*, 1945, **157**, 585, 595), who identified serine among the hydrolysates of these fractions. The structures of phosphatidyl ethanolamine (III) and phosphatidyl serine (IV) are shown below. The α-form of these compounds is given, although it should be emphasised that, as in the case of lecithin, the existence of α- and β-configurations has not yet been settled. These structural formulæ indicate clearly the essential difference between these two substances.

CH$_2$O.CO.R

CHO.CO.R

CH$_2$O.$\overset{-}{P}$O$_2$.OCH$_2$CH$_2\overset{+}{N}$H$_3$

(III)

CH$_2$O.CO.R

CHO.CO.R $\overset{+}{N}$H$_3$

CH$_2$O.$\overset{-}{P}$O$_2$.OCH$_2$CH

K+   CO$\overset{-}{O}$
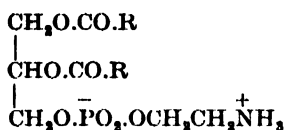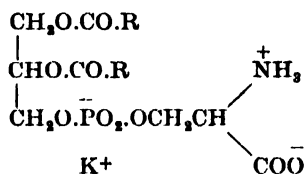
(IV)

In phosphatidyl ethanolamine, the molecule exists in nature in a state approaching electrical neutrality, possessing one positive and one negative charge. In phosphatidyl serine, the additional ionised carboxyl group lends to the molecule a net negative charge which necessitates salt formation. Preparations of this substance, isolated by extraction and precipitation with organic solvents only, contain one equivalent of kation, chiefly potassium with a small amount of sodium. Phosphatidyl serine must therefore be regarded as the alkali salt of a phosphatidic acid.

In recent years, phospholipins containing bound inositol have also been isolated from a number of sources including ox-brain, soya bean and tubercle bacilli. At the present time it cannot be stated definitely whether or not the different products are more or less impure varieties of a single substance. Although the ultimate chemical structure has been determined in no single case, the products all appear to be phosphatidic acids. Klenk and Sakai (*Z. physiol. Chem.*, 1939, **258**, 33) were the first to isolate a fraction from soya bean kephalin which upon acid hydrolysis yielded inositolmonophosphoric acid and glycerophosphoric acid. It now seems probable that this soya bean phospholipin is either identical with, or very similar to, the substance described by de Sütö-Nagy and Anderson (*J. biol. Chem.*, 1947, **171**, 761), who reported the isolation of an organic phosphoric acid, C$_9$H$_{20}$O$_{14}$P$_2$, from residues of tubercle bacilli grown on an artificial medium. Mild hydrolysis of this sub-

tance also gave equimolecular amounts of inositolmonophosphoric
ph glycerophosphoric acids.

th By contrast with the products found in soya bean and tubercle
acilli, much more experimental work has been carried out on the
hositol-containing phospholipin of ox-brain. In 1942, Folch and
Woolley (*J. biol. Chem.*, **142**, 963) showed the presence of bound
inositol in that fraction of an ox-brain kephalin preparation which
was least soluble in ethanol. More recently, Folch (*J. biol. Chem.*,
1949, **177**, 505) has succeeded in separating this compound from
accompanying phospholipins and, though his product was still not
completely homogeneous, it was sufficiently pure to attempt a
determination of its chemical structure. On partial hydrolysis it
yielded equimolecular amounts of inositolmetadiphosphate, glycerol
and fatty acid and evidence was presented to show that both
phosphate radicals were present in the form of diesters. Folch has
named this compound *diphosphoinositide* and has proposed the
somewhat vague structure (v); R and R' are stated to represent
unknown radicals. In view of the identification of the products of
hydrolysis, it is difficult to escape the conclusion that R and R'
represent fatty acid and glycerol radicals. Yet this conclusion is
unsatisfactory, for it would indicate the presence of an energy-rich
bond linking the phosphate and fatty acid radicals, while titration
studies provided no evidence for this. Diphosphoinositide exists in
nature as the Ca—Mg salt, and so conforms to the requirements of
a phosphatidic acid. The relationship between diphosphoinositide

$$O.PO_2.OR$$
$$|$$
$$CH$$

HCOH   HCOH   Ca++

HCOH   HCO.PO$_2$.OR'

HCOH

(V)
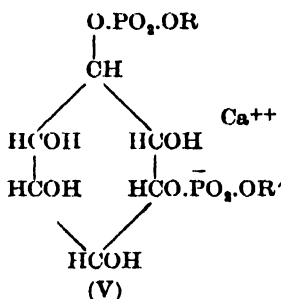
and the phospholipins isolated by Klenk and Sakai and by de
Sütö-Nagy and Anderson is still uncertain. The possibility should
be considered, however, that removal of the fatty acid radical from
diphosphoinositide would yield a compound which might be identical
with the products isolated from soya bean and tubercle bacilli.

It cannot yet be stated definitely that compounds of the type
of diphosphoinositide are the only inositol-containing phospholipins,

for Woolley (*J. biol. Chem.*, 1943, **147**, 581) has isolated from soya bean a substance which he terms *lipositol*. On complete hydroly₁ₑ lipositol yielded equimolecular amounts of *meso*-inositol, galacto·₁ phosphoric acid, oleic acid, mixed saturated fatty acid, ethanolamin and tartaric acid. Partial hydrolysis studies indicated that the inositol moiety was linked to galactose and also to phosphoric acid, while the ethanolamine was esterified with tartaric acid. It could not be determined whether the two fatty acid molecules were esterified with inositol or with galactose. The relationship between diphosphoinositide and lipositol is therefore by no means clear ; either they are two distinct compounds or else lipositol is a mixture of diphosphoinositide with galactolipin and perhaps other phospholipins, a possibility which has been suggested by Folch.

While the ultimate structure of lipositol is still in doubt, it is interesting to note that two very important physiological properties have already been claimed for it. Thus Rhymer, Wallace, Byers and Carter (*J. biol. Chem.*, 1947, **169**, 457) found that as little as 1 microgram suppressed the antibacterial activity of 60 micrograms of streptomycin with *Staphylococcus aureus* as the test organism ; a similar result was obtained using *Eberthella typhosum*. The authors pointed out that if lipositol is assumed to possess the galactose-inositol structure indicated by Woolley, then the possibility of a metabolite-antimetabolite relationship with streptomycin suggests itself.

More recently, Overman and Wright (*J. biol. Chem.*, 1948, **174**, 759), in a preliminary report, have observed an inhibitory effect of lipositol on thrombokinase, the lipoprotein enzyme which catalyses the conversion of prothrombin to thrombin. This very unexpected finding is of the greatest importance in the study of the mechanism of blood clotting, for crude kephalin has long been known to possess thromboplastic activity.

A complex phosphatidic acid of considerable diagnostic import-ance is the substance *cardiolipin*, isolated by Pangborn (*J. biol. Chem*, 1942, **143**, 247 ; 1944, **153**, 343) from ox-heart and found to possess characteristic serological properties. It has been known for many years that the serum of a syphilitic patient gives, with a heart extract, prepared under certain defined conditions, a complex capable of fixing complement ; this is the basis of the well-known Wassermann test. Recent work has shown that the activity of the heart extract is due to the combined effect of cholesterol, lecithin and cardiolipin and is greatest when these three components are present in certain determined proportions. Cardiolipin, on mild saponification, yields a mixture of linoleic and oleic acids in the approximate

ratio of 5 : 1, together with a complex polyester of glycerol and phosphoric acid. The products obtained on vigorous hydrolysis of this polyester suggest that it is derived from three phosphoric acid and four glycerol molecules. Such a compound would have six free alcoholic groups capable of being esterified with six molecules of fatty acid. In view of what has been said, it is possible that these consist of five molecules of linoleic and one of oleic acid. As isolated from ox-heart, the cardiolipin was in the form of the sodium salt. Tentatively, Pangborn (*J. biol. Chem.*, 1947, **168**, 351) has suggested the structure (VI) for the cardiolipin molecule. (R.CO— refers to the oleic ($C_{17}H_{33}CO$—) or linoleic ($C_{17}H_{31}CO$ --) acid radical. The α-linkage is shown, although the β-form is equally probable.)

$$R.CO.OCH_2.CH(O.CO.R).CH_2O.PO_2.OCH_2.CH(O.CO.R).CH_2O$$

$$PO_2 \quad 3Na^+$$

$$R.CO.OCH_2.CH(O.CO.R).CH_2O.PO_2.OCH_2.CH(O.CO.R).CH_2O$$

(VI)

Acetalphosphatide.—In 1927, Stepp, Feulgen and Voit, (*Biochem. Z.*, **181**, 284) extracted from brain and skeletal muscle by means of ethanol a substance which they termed *plasmalogen*. The most characteristic reaction of this substance was found to be its decomposition by acid or mercuric chloride to liberate a steam-volatile substance *plasmal*, which gave an intense violet colour with the fuchsin-sulphurous acid reagent. Plasmal was shortly identified by Feulgen, Imhauser and Behrens (*Z. physiol. Chem.*, 1929, **180**, 161) as a mixture of long-chain aliphatic aldehydes, chiefly palmitaldehyde and stearaldehyde. In 1939, Feulgen and Bersin (*Z. physiol. Chem.*, **260**, 217) succeeded in determining the structure of plasmalogen, which they renamed *acetalphosphatide*. Chemically, acetalphosphatide is closely related to phosphatidyl ethanolamine, the only difference being that the two fatty acid radicals in the latter compound are replaced by one molecule of fatty aldehyde combined in a cyclic acetal linkage. This acetal linkage was found to be highly resistant to alkaline hydrolysis, so that a separation from other ether-soluble phospholipins was readily achieved. Prolonged saponification, however, split off the ethanolamine portion of the molecule leaving a nitrogen-free phosphatidic acid, so-called *plasmalogenic acid*. The structures of the α-form of plasmalogen (VII) derived from palmitaldehyde and the corresponding plasmalogenic acid (VIII) are indicated. It is possible that plasmalogen also exists in a β-form (IX), for Feulgen and Bersin obtained from the naturally-occurring substance, by the action of warm mercuric

chloride solution, which must be regarded as very mild treatment, a mixture of the ethanolamine esters of α- and β-glycerophosphoric acids. Bersin *et al.* (*Z. physiol. Chem.*, 1941, **269**, 241) have synthesised the acetalphosphatide corresponding to (VII).

$$
\begin{array}{ll}
\text{CH}_2\text{O} & \text{CH}_2\text{O} \\
\quad\diagdown & \quad\diagdown \\
\quad\quad\text{CH(CH)}_{14}\text{CH}_3 & \quad\quad\text{CH(CH}_2)_{14}\text{CH}_3 \\
\quad\diagup & \quad\diagup \\
\text{CH.O} & \text{CHO} \\
| & | \\
\text{CH}_2\text{O.}\overset{-}{\text{P}}\text{O}_2\text{.OCH}_2\text{CH}_2\overset{+}{\text{N}}\text{H}_3 & \text{CH}_2\text{O.PO}_3\text{H}_2 \\
\quad\text{(VII)} & \quad\text{(VIII)}
\end{array}
$$

$$
\begin{array}{c}
\quad\quad\quad\quad\quad\quad\text{CH}_2\text{O} \\
\quad\quad\quad\quad\quad\quad\quad | \quad\quad\diagdown \\
\overset{+}{\text{N}}\text{H}_3\text{CH}_2\text{CH}_2\text{O.}\overset{-}{\text{P}}\text{O}_2\text{.OCH}\quad\quad\text{CH(CH}_2)_{14}\text{CH}_3 \\
\quad\quad\quad\quad\quad\quad\quad | \quad\quad\diagup \\
\quad\quad\quad\quad\quad\quad\text{CH}_2\text{O} \\
\quad\quad\quad\quad\quad\quad\quad\text{(IX)}
\end{array}
$$
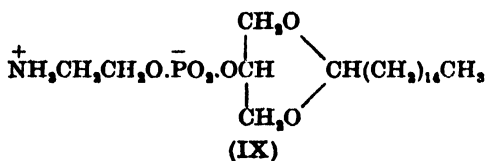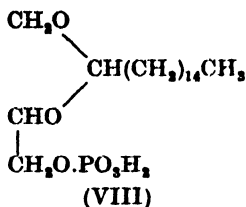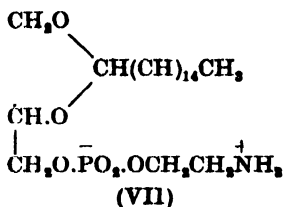
Sphingomyelin.—This phospholipin differs chemically from the lecithins and kephalins in that it is not a glyceride but contains instead the base sphingosine. In recent years the main interest has centred upon the elucidation of its structure. Thudichum in 1882 was the first to isolate sphingomyelin from a mixture of crude brain phospholipins. By prolonged hydrolysis he obtained sphingosine and prepared many of its salts which are crystalline substances. From determinations of its elementary composition, he assigned the formula $C_{17}H_{35}NO_2$ to the free base. Much later, doubts were expressed concerning the correctness of this formula and Klenk (*Z. physiol. Chem.*, 1929, **185**, 169) produced evidence that sphingosine was a straight-chain C_{18}-compound containing one double bond, two hydroxyl and one amino group. He proposed the formula $C_{18}H_{37}NO_2$ and showed that the double bond lay between C-atoms 14 and 15. It is only very recently, however, that the positions of the NH_2 and OH groups have been definitely located. Carter *et al.* (*J. biol. Chem.*, 1947, **170**, 285) were able to achieve this by demonstrating the inertness of N-benzoyl sphingosine towards periodic acid, an indication that the two OH groups are not adjacent.

In the sphingomyelin molecule itself, the fatty acid and sphingosine radicals are joined by an amide linkage which is fairly resistant to chemical hydrolysis. In this respect, sphingomyelin differs from the phosphoglycerides in which the fatty acids are present as esters. One of the hydroxyl groups of sphingomyelin is free and the other is esterified with phosphorylcholine, as in lecithin. The complete

structure of sphingomyelin is now believed to be represented by (x). The component fatty acids have been found mainly to belong

$$CH_3(CH_2)_{12}CH=CH.CH.CH.CH_2OH$$

$$\begin{array}{cc} | & | \\ O & NH.CO.R \\ | & \\ ^-PO_2 & \\ | & + \\ OCH_2CH_2N(CH_3)_3 & \end{array}$$

$$(X)$$
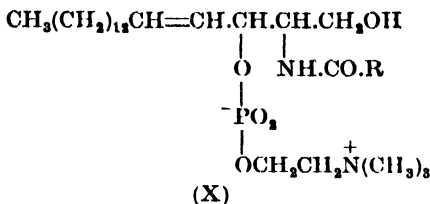
to the C_{24}-fatty acid series. While the amide linkage is resistant to chemical attack, it seems possible that it may be more easily broken enzymatically, for Booth (*Biochem. J.*, 1935, **29**, 2071) and King and Small (*Biochem. J.*, 1939, **33**, 1135) isolated *sphingosophosphoryl-choline* from ox-kidney and pig-pancreas, respectively. This finding could of course be alternatively explained by assuming that sphingosophosphorylcholine is a precursor of sphingomyelin.

REVIEWS.—Thannhäuser and Schmidt (*Physiol. Rev.*, 1946, **26**, 276) have reviewed work on lipides up to about 1945; brain lipides have been discussed by Bränte (*Acta physiol. Scand.*, 1949, **18**, Supplement 63).

(To be concluded in the next issue.)

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., F.R.S.E., The University, Glasgow.

THE INTERIOR OF THE EARTH : GEOCHEMISTRY.—In a paper " Über den Zustand des Erdinnern und seine Enstehung aus einem homogenen Urzustand," W. Kuhn and A. Rittmann (*Geol. Rundsch.*, **32**, 1941, 215–56), followed by W. Kuhn on the " Stoffliche Homo-genität des Erdinnern " (*Die Naturwiss.*, **30**, 1942, 689–96), an entirely different view of the constitution of the interior of the earth to that which is commonly accepted is propounded. The authors point out that if the earth was derived from the sun the initial matter of the new planet must have been very rich in hydrogen. The early history of the earth must then have been dominated by the loss of hydrogen with consequent superficial cooling. The mechanism of escape would involve a selective transport of relatively less volatile material than hydrogen, or such materials as silica which form volatile compounds with fluorine, etc., towards the surface, with the formation of a thin " Sial " rind, and an underlying thicker crust of " Fema." Thus far the authors are in accord with the orthodox view. The novelty of their hypothesis is the idea that, under the pre-vailing high temperature, pressure, and viscosity, and the decreasing

efficiency of separation obtaining towards the centre of the earth, there can have been no force adequate to bring about a further separation of any immiscible phase. In particular, the idea of an iron core at the centre of the earth must be abandoned. Kuhn and Rittmann believe that, just under the crust, a silicate-metal zone exists as an undifferentiated emulsion, and that undifferentiated solar material occurs from a half-radius depth to the centre of the earth.

The often-used analogy between the composition of meteorites and that of earth zones is criticised by the authors on the ground that the iron meteorites are far more conspicuous and durable than the stony types, and their relative abundance is therefore greatly exaggerated. The most important geochemical consequence of this new hypothesis is that it necessitates a completely different set of values for the abundance of elements in the earth as a whole. (The writer is indebted to Dr. D. T. Gibson, of the Chemical Institute, Glasgow University, for the gist of this paragraph.)

R. W. van Bemmelen has given a comprehensive summary of the physico-chemical evolution of the earth (" De physisch-chemische Ontwikkeling der Aarde," *Geol. en Mijnb.*, **11**, 1949, 1-21). He suggests that planetary systems are normal products of stellar evolution. In the earth the core of the planet may still consist of " mono-atomic gaseous matter in a hyper-critical state, enriched by siderophile elements " (Kuhn and Rittmann, *op. cit. supra*). Thereafter fractional condensation produced the successive earth shells, first the bi-atomic intermediate shell, and then the pleo-atomic silicate mantle. During the condensation of the last-named the composition gradually changed from sub-silicic (Sifema), to an ortho- or meta-silicic composition in the outer parts. Then began geological history *sensu stricto*. The source of energy is found in geochemical processes (hypo-differentiation). Orogeny, epeirogeny, isostatic anomalies, and deep-focus earthquakes are all explicable on this geochemical hypothesis.

In a paper on " Radial Diffusion and Chemical Stability in the Gravitational Field," H. Ramberg (*Journ. Geol.*, **56**, 1948, 448–58) shows that forces exist which tend to cause elements to diffuse in directions consistent with the present radial distribution of those elements in the earth. Because gravity influences chemical equilibrium, consideration of the thermodynamics of the earth requires understanding of chemical processes and stability in the gravitational field. Ramberg analyses the influence of gravity on the stability of mixed condensates (crystals or magmas), and asserts that this theoretical analysis supports the hypothesis of granitisation and meta-

somatism by upward diffusion of some of the elements. (This view is in direct opposition to others : *see*, for example, R. Jagitsch, "Geological Diffusion in Solid Phases," *Nature*, **164**, Sept. 17, 1949, 297–8.)

A criticism of certain abstruse points in Ramberg's paper is made by J. Verhoogen, and Ramberg makes a reply, the completeness of which the writer of these notes, not being a mathematician, is not competent to assess (" Radial Diffusion and Chemical Stability in the Gravitational Field." Discussion and Reply by J. Verhoogen and H. Ramberg respectively, *Journ. Geol.*, **57**, 1949, 93–7).

The composition and abundance of various types of meteorites have been used as data for confirming or denying views on the composition of the interior of the earth. Hence the study by H. Brown and C. Patterson on " The Composition of Meteoritic Matter III. Phase Equilibria, Genetic Relationships, and Planet Structure " (*Journ. Geol.*, **56**, 1948, 85–111) is thoroughly topical. Stress is laid on the following points : (*a*) distribution of elements between meteoritic phases ; (*b*) average composition as a function of the metal phase content ; (*c*) correlation between distribution of elements, thermochemical and thermodynamic data. It is thereby shown that if the observed distribution of elements represents equilibrium conditions, then equilibrium must have been established at temperatures of the order of 3000° C., and pressures of the order of 10^5–10^6 atm. The conditions of equilibrium vary from meteorite to meteorite in such a way that the greater the metal phase content the higher the temperature and/or pressure. The data strongly support the view that the origin of meteorites was in a planet similar to the earth in general physico-chemical aspects.

The first volume of a new periodical, *Memoirs and Notes from the Institute of Applied Geology of the University of Naples*, has made a good start with a number of important papers mainly on the connection between temperature, igneous action, and orogeny. A. Rittman (" La temperature nella crostre terrestre a l'orogenesi " *Mem. e Note dell' Institute d. Geol. Appl. dell' Univ. Napoli*, I, 1948, 21–38) elaborates his views on the connection between temperature and orogeny in the earth's crust which have already been dealt with in a previous issue (SCIENCE PROGRESS, Jan. 1950, 106). On the basis of the laws of physical chemistry he endeavours to establish temperature distribution and thermal behaviour down to a depth of 100 km. Further, he examines the influence of temperature conditions in causing subcrustal currents which, in turn, bear on the genesis and development of geotectonic movements.

F. Ippolytô follows with a paper on " Intorno ad una nuova

teoria sull' origine del Sial e sull' orogenesi " (*ibid.*, 39–62), which is a critical exposition of Rittmann's recent theory connecting petrogenesis and orogeny with the origin of Sial (*see above*). He discusses and rejects J. H. F. Umbgrove's objections to certain points, and goes on to suggest that Umbgrove's own theory of the origin of continents and oceans is invalid.

In a further paper A. Rittmann discusses the pre-geological pneumatosphere and its importance in geological problems (*ibid.*, 63–73). In the pre-geological evolution of the earth he shows that, in addition to the primitive crust of alkaline basalts, there was formed a shell of granite-aplite composition by the action of the primordial atmosphere (pneumatosphere) upon the original crust. From this shell and its successive transformations arose the first Sial. (The writer of these notes is indebted to Mr. A. D. MacKinven, of the Italian Dept., University of Glasgow, for translations.)

W. Wahl's paper on " Isostasy and the Origin of Sial and Sima, and of Parental Rock Magmas " (*Amer. Journ. Sci.*, **247**, 1949, 145–67) covers so much ground that the commentator can hardly do more than transcribe the headings. The author states that his aim has been to discuss " the geochemical processes originating and taking place on account of isostatic adjustment and its extreme consequences as they manifest themselves in orogenic zones." Wahl bases his views on Vening Meinesz's theory of orogenic movement and geosynclinal formation expressed in his paper of 1948 (SCIENCE PROGRESS, Jan. 1950, 104). He then goes on to discuss the geochemical consequences of isostatic adjustment, especially the melting of the " sialic root." The " palingenic magmas " produced in this way cannot possess much eruptive power, and will probably only be able to impregnate the adjacent rocks just above them. Wahl next suggests that, during orogeny, four " parental magmas " may appear: spilitic ranging to picritic ; granodioritic differentiating in the usual way ; basaltic magma ; and, finally, potash-granitic magma of composition close to the " granite eutectic." Kratogenic parts of the earth's crust also have their distinctive magmas : " plateau basalts," olivine-rich basalts, foyaitic and essexitic magmas, etc. The author also deals with the origin of Sial and Sima, the origin of the layering of the crust, and the nature of the original crust of the earth which he finds to be " meteoritic chondritic tuff." This paper is worthy of much more extended comment and criticism.

In his paper on " Crustal Layers and the Origin of Ore Deposits," W. Q. Kennedy (*Schweiz. Min. Petr. Mitt.*, XXVIII, 1948, 1–8) has related the problem of the origin of ore deposits to his conception of plutonic and volcanic associations in the crust of the earth. In

his view ore deposits are predominantly associated with rocks of the plutonic association, which are believed to be derived from the granitic layer of the earth's crust and, perhaps, the tholeiitic layer which was derived by interaction of the primæval basaltic shell with the underside of the contents. A subsidiary problem is the association of metallic ores with specific types of magma and specific sectors of the earth's crust. This points to pre-existing localised concentrations of metallic elements within the crust and, more specifically, within the granitic layer. How these concentrations arose is a matter for speculation, but Kennedy suggests that they originally occurred within the sedimentary material incorporated in granitic terranes by processes of previous sedimentary and metamorphic differentiation.

D. T. Gibson has written a most valuable survey of " The Terrestrial Distribution of the Elements " (*Quart. Reviews, Chem. Soc. III*, No. 3, 1949, 263–91) which, as it has been carried out from the point of view of a chemist, is full of the most interesting sidelights for the geologist. Dr. Gibson utilises V. M. Goldschmidt's well-known scheme for the geochemical history of the earth as a framework for his discussion, and is especially illuminating on the fate of the rare elements during the second phase-parting, *i.e.* the crystallisation of magmas. There is also a good discussion of the geochemistry of the atmosphere, the ocean, and especially of weathering as the agent which makes many elements, rare and less rare, available for economic uses.

Discussing " Oxidation and Reduction in Geochemistry," B. Mason (*Journ. Geol.*, **57,** 1949, 62–72) finds that the processes of oxidation and reduction are correlated with the geochemical cycle which runs from the original magmatic state, through weathering, diagenesis and lithification, to metamorphism, and finally, reconstitution to magma. The magmatic environment is strongly reducing, and igneous rocks show a low state of oxidation. Weathering in contact with free oxygen, on the other hand, has a high oxidation potential. In diagenesis there is again some degree of reduction which becomes progressively greater in the metamorphic grade. Nevertheless, a high state of oxidation may persist through the metamorphic process owing to disequilibrium, and a high Fe_2O_3/FeO ratio is a useful indication of original sedimentary characters. The significance of oxidation potentials in geochemistry is specially marked in the frequent concentrations of rare elements in deposits formed under extreme oxidising or reducing conditions.

According to G. C. Kennedy in a paper on " Equilibrium between Volatiles and Iron Oxides in Igneous Rocks " (*Amer. Journ. Sci.*,

246, 1948, 529–49) evaluation of the ferrous-ferric ratio in igneous rocks throws light on several problems of volcanology and petrogenesis. The equilibrium constant for the reaction $2Fe_2O_3 \rightleftharpoons FeO + O_2$ is known for the temperature range 1200° C.–1420° C., and can be computed for lower temperatures. It is possible to compute therefrom the partial pressure of O_2 necessary to maintain a given ferrous-ferric ratio in a silicate system. From these considerations it is deduced that the gases of Halemaumau volcano (Hawaii) contained approximately 0·163 vol. per cent. of free H_2; and if the magmas of certain Californian gabbros were of similar composition to the Hawaiian lavas it can be computed that they crystallised under a mean vol. pressure of about 250 atm. Further, studies of the rate of conversion of FeO to Fe_2O_3 in a laboratory melt of basalt exposed to atmospheric oxygen show that the rate of surface heating of a lava due to oxidation of the contained iron will be negligible in comparison with the rate of cooling by radiation.

S. J. Shand has dealt with " The Genesis of Intrusive Magnetite and Related Ores " (*Econ. Geol.*, XLII, 1947, 634–6). Most geologists are agreed that these ores have been segregated in some way from the rocks into which they have been injected. They have been ascribed to the crystallisation of late-stage magmatic residues. But there is no solvent that can dissolve and re-precipitate these ores. Shand solves the problem by showing that the ferrous oxide which is now known to form a major constituent in residues from the crystallisation of gabbroidal magmas must be in the condition of a ferrous oxide hydrosol, and that it will be precipitated as magnetite by a process of self-oxidation according to the equation :

$$3Fe(OH)_2 = Fe_3O_4 + 2H_2O + H_2$$

(Very similar ideas were put forward in regard both to magnetite and sulphide ores in a much-neglected memoir by W. H. Goodchild, " Evolution of Ore Deposits from Igneous Magmas," *Mining Mag.*, 1918.)

In a paper on " Titanic Iron Ore formed by Dissociation of Silicates in Granulitic Facies," H. Ramberg (*Econ. Geol.*, 43, 1948, 553–70) shows that rocks of charnockitic affinities, including anorthosites, are recrystallised under granulitic facies conditions. The stability relations of some silicates (hornblende, biotite, sphene, titanaugite) require the liberation of titanium and some iron from the silicate lattices under the above conditions. This agrees with the fact that titaniferous iron ores tend to develop in rock complexes that have been recrystallised in the granulite facies, and suggests genetic relationships between the liberation of ore elements

from the silicates, and the segregation of ore bodies in, or near, basic noritic rocks and anorthosites.

H. E. Suess has discussed " Die Haüfigkeit der Edelgase auf der Erde und in Kosmos " (*Journ. Geol.*, **57**, 1949, 600–7). The cosmic abundance of the rare gases is now known with sufficient accuracy to permit a comparison with the corresponding data for the earth's atmosphere. Comparison of these values with those for the composition of the earth and its atmosphere shows that the relative abundance of xenon is about 10^7 times smaller on the earth than in the universe, whereas for neon this figure exceeds 10^{11}. A separation of these two gases has obviously taken place during the evolution of the atmosphere. Its cause cannot be explained by chemical absorption or solution processes, and selective diffusion from the earth's atmosphere during geological time must be assumed.

An investigation of the origin of carbon in graphite, carbon-bearing schists, carbonaceous accumulations in phyllite including the problematic fossil *Corycium enigmaticum*, and the bitumen known as shungite, all from the Finnish Pre-Cambrian, has been made by K. Rankama (" New Evidence on the Origin of Pre-Cambrian Carbon," *Bull. Geol. Soc. Amer.*, **59**, 1948, 389 416). In addition to the isotope ratio C^{12}/C^{13} the CuO, V_2O_5, and MoO_3 contents of the samples were determined. Geological evidence and trace-element determinations make probable the division of carbon into organic and inorganic groups. The C^{12}/C^{13} determinations are held to furnish definite proof of this, and also of the organic nature of *Corycium*, which thus becomes a real fossil of Late Archæan times, and the oldest yet recorded with certainty.

In " A Note on the original Isotopic Composition of Terrestrial Carbon," K. Rankama (*Journ. Geol.*, **56**, 1948, 199–209) discusses the primordial isotopic composition of terrestrial carbon with reference to astrophysical and geological evidence on the possibility of the fractionation of isotopes. He suggests that the original isotopic composition of terrestrial carbon corresponds to that found in meteorites, where the C^{12}/C^{13} ratio ranges from 89·5 to 92·0. Earlier investigations have shown that inorganic processes on the earth tend to concentrate the heavier isotope C^{13}, whereas C^{12} is accumulated by organic processes. Rankama illustrates the cycle of C^{12} and C^{13} between the atmosphere and the sea by means of an illuminating diagram. He also gives a short discussion of the isotopic composition of O, Fe and Cu in meteorites, terrestrial rocks, and minerals, as compared with that of carbon.

In " A Note on Two Aspects of the Geochemistry of Carbon," G. E. Hutchinson (*Amer. Journ. Sci.*, **247**, 1949, 27–32) criticises

Rankama's assumption that the C^{12}/C^{13} ratio in meteorites corresponds to that of the earth as a whole, and suggests that the meteoritic ratio does not provide a reliable standard. As it is reasonably certain that the earth lost a considerable amount of carbon quite early in its history, the mean terrestrial C^{12}/C^{13} ratio is probably a function of the mass of the earth, and identity with the meteorite ratio could only be expected if the meteorites were produced by the breaking-up of a planet of the same mass as the earth. Rankama's figures for the C^{12}/C^{13} ratio in *Corycium* differ significantly from those for igneous carbon, but not from meteoritic carbon. Hence his view that *Corycium* is an Archæan fossil is only valid if some difference is assumed between meteoritic carbon and that of the accessible lithosphere.

In a paper on "The Geochemistry of Radiogenic Strontium," L. H. Ahrens (*Min. Mag.*, XXVIII, 1948, 277–95) discusses the abundance of radiogenic strontium in the earth's crust as a whole, and the distribution of this element in various minerals and rocks, especially those of igneous origin. As rubidium is β-radioactive and breaks down slowly into a stable isotope of strontium, small quantities of strontium have been accumulating in various minerals since the first consolidation of the crust. The abundance of radiogenic strontium in the crust is estimated at 0·00025 per cent. Minerals relatively rich in rubidium will contain most of the strontium. As rubidium is mainly concentrated in potassium-rich minerals it is only in granitic rocks that the proportion of Sr is likely to be appreciable.

In two papers, "Geochemical Studies of some of the Rarer Elements in South African Minerals and Rocks, No. 2, The Geochemical Relationship between Thallium and Rubidium in Minerals of Igneous Origin" (*Trans. Geol. Soc. S. Africa*, **48**, 1945, 207–31), and "The Unique Association of Thallium and Rubidium in Minerals" (*Journ. Geol.*, **56**, 1948, 578–90), L. H. Ahrens has studied the remarkable geochemical relations between two rare elements in minerals. Thallium and rubidium are found only in potassium minerals and in the rare cæsium mineral known as pollucite. The mean weight per cent. ratio of Rb_2O/Tl_2O was determined as 100, and the great majority of ratios fell within the range 35 to 300, the extreme limits being 10 and 650. The ratio seems to be independent of the type of host-mineral but it may vary from area to area. The reason for this close association of thallium and rubidium is that the radii of their ions are identical, and in certain respects their chemical properties are similar.

The abundance of thallium in the earth's crust is estimated by

Ahrens as 0·0003 per cent. by weight. In a "Note on the Geochemistry of Thallium," K. Rankama (*Journ. Geol.*, **57**, 1949, 608–13) gives the value of 0·6 gr. per ton for the abundance of thallium in igneous rocks. Rankama discusses the geochemical coherence of the pair Rb—Tl in comparison with the pairs Ga—Al, Cb—Ta, Zr—Hf, and pairs in the group of lanthanum and the lanthanides. He concludes that Zr—Hf probably form a more coherent pair than Rb—Tl.

E. B. Sandell has discussed "The Gallium Content of Igneous Rocks" (*Amer. Journ. Sci.*, **247**, 1949, 40–8). Analyses of composite samples give a Ga/Al weight ratio varying from $1·5 \times 10^{-4}$ or even less in basic rocks to 3×10^{-4} in high-silica granites. There is some indication that gallium may replace ferric iron in minerals. The abundance of gallium in the upper part of the lithosphere is estimated at 15 parts per million. Sandell gains the impression of great uniformity in the gallium content of the common igneous rocks irrespective of age or locality.

In a paper on "The Radium Content of Varved Clays and a Possible Age of the Hartford, Conn. Deposits" W. D. Urry (*Amer. Journ. Sci.*, **246**, 1948, 689–700) shows that, while the radium content of the individual varves remains practically constant, the figures for the summer and winter portions of the varves vary rhythmically. These phenomena are tentatively explained by the theory that they are due to a disturbance of the radioactive equilibrium, in such a way that there is a greater concentration of uranium relative to ionium in the winter than the summer clay. It is stated that while this view is plausible it is far from proven. If it is valid it provides a means of dating the Hartford Clay, and a tentative figure of 18,000 years is derived for the varve 3700. This agrees fairly well with estimates based on independent data.

W. D. Urry presents No. VI of his series of papers on "Radioactivity of Ocean Sediments" entitled "Concentrations of Radioelements in Marine Sediments of the Southern Hemisphere" (*Amer. Journ. Sci.*, **247**, 1949, 257–75). In previous papers dealing with sediments in the northern Hemisphere it has been shown that the mode of variation of Ra concentration below the ocean floor affords a method of determining time in oceanic sediments. This valuable method is now applied to sediments in the southern oceans. The curves of Ra content as a function of depth below the ocean floor are similar in all qualitative respects to curves obtained for cores from the North Atlantic and Caribbean Sea (see SCIENCE PROGRESS, July, 1948, 508–10).

A. F. Mohamed has determined organic carbon and nitrogen in

38 sediments from the floor of the Red Sea (" The Distribution of Organic Matter in Sediments from the Northern Red Sea," *Amer. Journ. Sci.*, **247**, 1949, 116–27), and discusses the distribution of the elements concerned. The organic matter content is very small and the C : N ratio (5·2) is low. Both materials exhibit regional variations which are ascribed to different environmental conditions of deposition. The mean C : N ratio is in close agreement with the proportion of these elements in mixed plankton.

Agriculturalists have long been interested in the minor element content of vegetation and of the soils in which it grows. The direct relation between the metallic content of vegetation and soils forms the basis of a biogeochemical method of prospecting for metals in drift-covered and forested areas which was first developed in Finland (SCIENCE PROGRESS, July 1948, 511–12). In a paper on " Biogeochemical Prospecting for Copper and Zinc," H. V. Warren and C. H. Howatson (*Bull. Geol. Soc. Amer.*, **58**, 1947, 803–20) have investigated zinc and copper areas in British Columbia along these lines, and find that the Zn and Cu contents of trees and lesser plants may reflect, to a striking extent, the presence of concentrations of these elements in the underlying soils or rock formations.

The paper by H. V. Warren and R. E. Delavault, " Further Studies in Biogeochemistry " (*Bull. Geol. Soc. Amer.*, **60**, 1949, 531–60), first outlines a number of the analytical methods employed in the investigation of the metallic contents of vegetation. It is then shown that twigs, rather than leaves, needles, or even fruit, are probably the most satisfactory parts of trees to furnish significant data. If this point is substantiated it will be possible to carry on biogeochemical prospecting in winter as well as in summer. The methods have been tested on samples from the Britannia and Sullivan Mines (B.C.). The results suggest that the Zn : Cu ratio is more important in biogeochemical prospecting than the absolute amounts of these metals in the samples.

We may call attention to a useful compilation by H. E. Hawkes, " Annotated Bibliography of Papers on Geochemical Prospecting for Ores " (*U.S. Geol. Surv. Circular 28*, 1948, 5 pp.). It lists most of the publications on this comparatively new line of geochemical research.

A valuable summary of " Geochemical Researches in Japan," with a good bibliography, has been made by K. Yamasaki (*Journ. Geol.*, **57**, 1949, 414–18). Minerals and shales have been studied for rare elements. Many analyses of Japanese igneous rocks have been made, as well as an estimate of their average composition. Japanese chemists have specially concentrated on geochemical studies

of hot springs, lakes and seas, and their deposits. In connection with a search for helium, a study of natural gases has been made by N. Yamada.

PEDOLOGY. By G. V. JACKS, M.A., Commonwealth Bureau of Soil Science, Rothamsted Experimental Station, Harpenden.

SOIL FORMATION.—Many definitions of soil have been attempted, but it is probably as impossible to define soil completely as it is to define a species or, more appositely, a plant association, of which a soil is the natural complement. Recent work on soil formation has stressed its biological nature, and less emphasis is placed than formerly on soil as a product of geological weathering. A. A. Rode *Pochvovedenie*, 1946, 400-1) points out that soil is part of a wider complex—" biogeocenose "—embracing the soil, the lower layers of the atmosphere, surface and ground waters and living organisms, particularly the vegetation. Soil formation is regarded as a cyclic process subject to rhythmic fluctuation depending on the varying intensity of solar radiation. The most important are the daily and yearly cycles, but there are others such as the eleven-year sunspot cycle. These cycles are never closed, owing to the continuous operation of other non-cyclic and irreversible processes, of which the chief is the weathering of minerals. These cause permanent changes in the soil, the result of which is known as soil evolution. To the five " orthodox " soil-forming factors—climate, parent rock, topography, living organisms and time—that are usually cited as determining the nature and direction of soil evolution Rode adds three more—gravitation, surface and underground water, and agriculture.

Rode's, like all recent Russian views, have been much influenced by the teachings of the late V. R. Williams of Moscow whose theories are briefly summarised by C. C. Nikiforoff (*Soil Sci.*, 1949, **67**, 219–30). Williams developed the concept of a continuous, universal soil-forming process, successive stages of which are represented by different soil types. The stages gradually replace one another in time as well as in space. Soil formation consists of a succession of evolutional cycles during each of which every stage reappears. But during each stage the soil acquires certain permanent characteristics which make it different from its condition at the same stage of a previous cycle. The cycles thus develop into a sort of evolutional spiral.

Nikiforoff states that this theory of " autogenic " evolution is based on the assumptions (1) that soil evolution is affected continuously by certain progressive processes (*e.g.* weathering), and

(2) that concurrently with these processes certain specifically pedogenetic processes occur which are cyclic in the sense that each process develops to a peak in its effect on the soil and then dwindles to vanishing-point. These assumptions are, however, purely empirical. Nikiforoff points out that weathering as a continuous, irreversible process would long since have led to a condition, over most of the earth's surface, in which all active minerals would have been removed from the pedosphere had not weathering been accompanied by continuous processes of deflation, erosion, etc. This continuous removal of senile weathering products and the renovation of the weathering crust from unweathered rock indicate that soil parent material is not a static product. " The A horizon of every mature, non-cumulative soil develops from the material that previously passed through the stage of the B horizon, rather than directly from the C material." In a cumulative soil (*i.e.* one formed by gradual sedimentation of parent material) the A horizon develops from fresh sediments settled on the surface, and the B horizon develops from sediments that have passed through the stage of the A horizon.

B. B. Polynov (*Pochvovedenie*, 1948, 3–13) defines soil as the product of the interaction of living organisms with mineral rocks, and indicates the enormous influence soil formation has had on the chemistry of the earth's surface. In the continuous cycle of elements through organisms and back to the soil some elements are held back more than others, so that the relative proportions of the elements in the soil gradually change as a result of the action of organisms as well as of the differential removal or accumulation by leaching of the elements of the original rock. Thus, whereas according to physico-chemical theory the relative migration of the elements K, Na, Ca and Mg in the earth's crust should be in the above order, it is in fact, over large parts of the earth's surface, in the order Ca, Na, Mg, K. The difference in these orders is caused partly by the nature of soil colloids and partly by biological forces which prevent the complete removal from the soil of these elements which are contained in the organisms inhabiting the soil. In particular, the relatively high mobility of calcium in soils is a direct consequence of the biological nature of the soil-forming process.

It is possible to explain many of the characteristics of soil types in terms of either geomorphology (*e.g.* catena relationships) or plant-soil relationships or, more generally, of both. It is shown that the relative mobility of Ca and Si in soils of the chernozem zone is connected with the high content of these elements in the natural vegetation. Again, the absence of podzolisation and the richness

of the soils in sesquioxides in the humid sub-tropical red-earth zone are related to the ready absorption of iron and aluminium by sub-tropical plants and the almost unbroken growing period which keeps the sesquioxides in continuous circulation.

Polynov tries also to generalise the concept of the *catena*, or topographically related association of soil types, pointing out that, although the surface forms of the earth, resulting from the action of the soil-forming factor water, are many and varied, they can all be classed as one or other of three basic types of surface that leave their impress on the soils formed on them. One type occurs on watershed areas which have deep water-tables and receive surface waters only from atmospheric precipitations, part of which evaporates, part seeps downwards through the soil and part runs off the surface towards a lower-lying position. This results in a soil whose evolution is characterised by progressive leaching and some erosion, and to which the term eluvial, or preferably *transluvial*, is applied. Leaching, however, is never complete owing to the continuous return to the surface soil of substances absorbed by vegetation.

Another type of surface occurs near the bottom of a valley where the soil surface is close to the permanent water-table. Here a considerable part, and under conditions of low rainfall the greater part, of the soil moisture is derived from the ground water which will contain, among other solutes, some of the material leached from the higher-lying transluvial soil that under arid or semi-arid conditions will be precipitated by evaporation near the soil surface. Soils formed in these positions are termed *superaqual*. They tend (apart from the organic cycle) to gain or lose soluble elements according to whether their moisture is derived predominantly from the ground water or from the atmosphere. They obtain further material by erosion of transluvial soils.

The third type of surface occurs where the water table is above the soil surface, and is termed *subaqual*. Soils related to such surfaces are alluvial, or are formed on lake or river beds. They receive considerable amounts of solid as well as dissolved material derived from the transluvial and superaqual parts of the landscape.

The pattern of soil associations in arid regions offers a good illustration of this topographical interrelationship of soil types. The eluvial (transluvial) members of the association are characterised by a scanty, xerophytic vegetation, resulting in a weak influence of organic life on soil evolution. Its strongest influence is expressed in the cycle of calcium which circulates through the vegetation and surface soil, but does not migrate to any depth. The soils (serozems) are calcareous, but not or only weakly saline. Chloride and sulphate

ions, on the other hand, are leached out, saturating the ground water, and accumulate in the superaqual soils which are saline (solonchaks), carrying a halophytic vegetation. Subaqual soils occur in closed basins and depressions.

Analogous associations of soil types occur in the semi-arid steppe (chernozem) zone and in the humid forest (podzol) zone. In the chernozem zone the soils are characterised by the complete disappearance of sulphates and chlorides from the soil profile and by the high mobility of calcium in the profile, determined by the high biological activity of the plant cover. In the podzol zone, calcium has largely disappeared from the soil profile, and soil formation is characterised by the mobility of the sesquioxides, which are immobile in both chernozem and serozem zones.

The development of the major soil types is thus seen to be related not only to climate and topography, but also to time. In the series serozem—chernozem—podzol each represents a distinct stage in the general process of landscape development. The first is characterised by mobility of sulphates and chlorides whose " index of mobility " in nature is 10 times that of Ca, Na, Mg and K, whose index is, in turn, 100 times that of Fe, Al and Ti. Polynov had earlier (1934) developed the idea of a universal weathering process, consecutive stages of which were characterised by the progressive removal of increasingly insoluble groups of substances from the crust of weathering; he has now extended his idea to include the action of living matter on weathering rock and to explain the evolution of soil types genetically related in time.

V. A. Kovda (*Pochvovdenie*, 1944, Nos. 4–5, 144–58), in a study of the effect of living matter on the movement and accumulation of salts in soils, shows that large quantities of salts are brought into the biological cycle of soil formation by the growth and decay of plants. In steppe vegetation calcium, potassium and phosphorus predominate and contribute considerably to the potential fertility of the soils. In arid regions chlorides and sulphates of sodium and calcium are mainly involved. In areas of saline soils with high water-table, however, the accession of salts through the activity of vegetation is insignificant compared with the amounts derived from ground waters. If the water-table falls the vegetation changes to a type in which calcium and potassium sulphates and phosphates predominate, thereby assisting the process of desalinisation. The quantity of salts involved in the annual biological cycle in steppe areas is of the order of 150–600 kg. per hectare.

C. G. Stephens (*Trans. Roy. Soc. S. Australia*, 1947, **71**, 168–81), following H. Jenny (*Soil Sci.*, 1946, **61**, 375–91), develops a mathe-

matical expression of soil formation in which soil is represented as a set of differentials in which the variables are the soil-forming factors climate, organisms, topography, height of water-table, parent material and time. These variables may have both dependent and independent status. Each soil is a synthesis of functions of all the variables, and it is possible, by means of quite simple diagrams, to show the genetic interrelationships of all soil types occurring over an area embracing, for example, 600 square miles. Stephens points out that, although lapse of time since the beginning of soil formation is a measure of the actual age of the soil, it is not a measure of soil maturity, which is a characteristic of the soil itself and should be regarded as a dependent variable entering into the integral which expresses the soil ensemble.

WEATHERING OF CLAY MINERALS.—M. L. Jackson, S. A. Tyler et al. (*J. Phys. Coll. Chem.*, 1948, **52**, 1237–60) present a " stability series " or weathering sequence for clay-size minerals in soils. The sequence is : gypsum ; calcite ; olivine ; hornblende ; biotite, glauconite, etc. ; albite, etc. ; quartz ; illite, muscovite, etc. ; hydrous mica intermediates ; montmorillonite ; kaolinite, halloysite ; gibbsite, boehmite ; hæmatite, goethite ; anatase, rutile, etc. It is shown that there is a close correlation between crystal structure and stability, the order with silicates being : independent SiO_4 groups $<$ chains and bands $<$ frameworks (feldspars) $<$ linked tetrahedra (quartz) $<$ sheets. The association of alumina sheets with silica sheets confers greater stability, as in the common clay minerals. In the early stages one or two minerals are usually dominant in the clay, the others decreasing in amount with remoteness in the sequence. One or more stages may be absent, especially those occurring after quartz.

The rate of weathering is postulated as a product of an intensity factor (temperature, water, oxidation, etc.) by a capacity factor (specific surface, nature of mineral). The sequence proceeds under increasing acidity and oxidation, but arrest may occur under conditions of deficient leaching and reversal takes place in sediments.

The mineral composition of soil clays follows the weathering sequence geographically and in accord with the variation in intensity factors as controlled by climate and time. The rate of weathering increases with decreasing particle size, but beyond the illite stage specific surface is less important than the lattice factor. A discussion of podzolisation and lateritisation indicates that the first occurs under reducing surface conditions, the second under good oxidation. There should be a complete gradation from podzolisation to lateritisation and intermediate stages such as podzolic-laterite can occur.

The gradation is illustrated by the decrease in the quartz content of a series of soils and soil clays. Red and yellow podzolic soils are considered to have developed on previously formed " lateritic " soils.

It is suggested that soils in general have not reached a steady state, but are slowly advancing through further stages in the weathering sequence.

BOTANY. By PROFESSOR W. H. PEARSALL, D.Sc., F.R.S., University College, London.

CYTOLOGY.—The structure of chloroplasts has been studied mainly in living material because most of the established methods of fixation seriously distort the characteristic features. Recently, however, a re-examination of the structure of the plastid has been carried out by J. G. Bald (*Aust. J. Sci. Res. B.*, **1**, 452, 1948) in connection with an attempt to identify the cytological effects associated with virus infections. The material used was mainly epidermal strips with adjacent cells from tobacco leaves, and two fixatives have been employed. The first is a mixture of alcoholic chromic acid and iodine in aqueous potassium iodide solution (Lugol's iodine). This is used to demonstrate the stromatic structure of the· plastid. The second fixative demonstrates the structure of certain cuboidal bodies present in the cells. This is alcoholic acetic acid containing equal amounts of cerium nitrate and carminic acid.

With these stains the plastids are found to contain an outer, somewhat reticulate stromatic surface which surrounds starch grains apparently embedded in a clear cytoplasm. The outer stroma in tobacco always has a circular gap, at the edge of which, or near to it, is a single small refractile deeply-staining granule in the outer stromatic layer. There is some evidence of a membrane (semi-permeable) around the plastid.

Associated with the chloroplasts and usually close to them are cuboidal or spherical bodies larger than the maximum size (0.8μ) usually associated with mitochondria. These bodies stained in a manner that suggested two components, the strongly staining body being associated with a vesicle-like attachment. Some evidence was obtained that these bodies tend to be combined with or included in the plastids during darkness. They were normally separated from them after exposure to strong light.

Another series of papers by this author (*Phytopathology*, **39**, 395, 1949, and *Amer. J. Bot.*, **36**, 335, 1949) deal with the development of various methods of fixation, including those mentioned above, and suitable for staining the special features of virus-infected cells. The fixatives are of three main types, the first containing iodine and

alcohol, the second containing iodine and chromic acid but no alcohol, and the third built up around concentrated acetic acid as the medium preparing the virus for staining. After fixing with such solutions, the fixed material is then stained with Giemsa stain under such conditions that the virus inclusion will take up these dyes more strongly than any other cell inclusions, except possibly the nucleolus. These methods are selective for the virus types tested when the cells are mature or well beyond the meristematic stage. They have been used upon a number of virus-infected tissues of different types and the appearance of stained cell inclusions follows the distribution and the types to be expected if the material stained is virus. Thus, for example, the stained inclusions are confined to cells around the phloem in the case of virus X in potato plants. The tobacco mosaic, studied in greatest detail, induces first the appearance of granules in cloudy stained areas in infected cells, but later the granules aggregate into cell inclusions of a tabular or spherical nature. There are also amœboid-like inclusions, in which the stained material is of a reticulate nature. No such appearances are found in normal cells.

In order to explain the nature and origin of these inclusions, Bald has found it necessary to deal first with the normal cytology of leaf plastids, as already mentioned at the beginning of this article. A further paper deals with the nature and development of the amœboid or reticulate inclusion bodies developed after virus infection becomes effective (*Aust. J. Sci. Res. B.*, **1**, 458, 1948). Structurally these closely resemble abnormal plastids, but are larger and usually of distorted and amœboid shape, with more than one gap in the outer stroma, and often with abnormally large angular or cubical inclusions of strongly staining material. The author points out that this latter feature is infrequent in normal plastids and he suggests that their connection has some association with the multiplication of the virus. The paper closes with a critical discussion of the virus-cell relations and virus multiplication.

CYCLES OF GROWTH. In a series of papers from East Malling by L. B. Singh (*J. Hort. Sci.*, **24**, 45, 123 and 159, 1948) a further attempt is made to analyse the factors controlling biennial bearing in fruit trees, that is, the marked tendency shown by some varieties of tree to produce large crops of fruit in alternate years, so that " on " and " off " years succeed one another regularly. The first of these papers is a useful review of the literature, as a result of which the author concludes that no single factor is responsible for the phenomenon, but rather a complex of factors.

The second paper is especially interesting. It breaks new

ground in attempting to correlate all the growth phenomena on the trees studied with their fruit production.

The data were obtained from apple-trees—particularly the variety Miller's Seedling which is markedly " biennial " at East Malling.   Some records for Lane's Prince Albert, Blenheim Orange (" biennial ") and Ellison's Orange and Ribston Pippin (" regular ") are also given.

The analysis of the data shows that, in years with heavy crops, there is a parallel reduction in trunk thickening and presumably therefore in cambial activity.   A similar negative correlation between crop size and amount of root growth was established.   On the other hand, there was normally no significant difference in the amount of shoot growth during " on " and " off " years, although the extension shoots of bearing (or " on " year) trees start growing sooner and grow faster than those which are not bearing.   It is suggested that this may affect the differentiation of fruit buds which occurs at this time.   This is regarded as highly significant, because in Miller's Seedling the biennial habit proves to be associated with abundance or scarcity of blossom production.

A further point is that, during the critical period of flower-bud formation, records show that the leaf-area per spur is nearly twice as much in " off " year spurs as it is during heavy cropping years. It appears, therefore, that flower bud initiation is associated with a much larger leaf area.   In contrast, the leaves are darker green at the end of August during the " on " year.

The third paper in this series deals with possible methods of controlling the crop production in biennial bearing trees.   Two main methods were tried during the " on " year, namely partial defoliation or blossom-removal.   Defoliation was done either by hand or by spraying with chemical sprays (sodium chlorate, copper sulphate, lime sulphur or tar oil).   This was not altogether satisfactory on account of the difficulty of deciding and ensuring the required proportion of defoliation.

Blossom-removal was done either by destroying flower buds by bud-rubbing or else by removing the open flowers by hand. The former was more effective and, by reducing the blossoms to about 20 per cent. of those laid down, the crop was reduced proportionately.   A nearly normal crop, however, was obtained in the following year and the figures suggest that a less severe pruning might well spread out the total yield evenly between the two years. The principal difficulty of these treatments is that they are carried out by hand.   A spraying method, for example, would be more rapid and probably cheaper.

ANTIBIOTICS.—The literature on substances showing antibiotic properties continues to grow so rapidly that little or no attempt can be made to review it comprehensively. An interesting group of papers covering one large field has been prepared by H. A. Spoehr and four collaborators, dealing with fatty acid antibacterials from plants (*Carnegie Inst. Wash.*, *Publ.* 586, 1949). This describes investigations following the observation by R. Pratt (*Amer. J. Bot.*, **27**, 52 and 431, 1940) that the alga *Chlorella* produced something in the culture medium which reduced the growth rate of the alga. Subsequently this material was named *chlorellin* and shown to be antibacterial. The material was present in very low concentrations and large-scale culture methods (which are described) were necessary in order to produce sufficient quantities for examination. After much investigation it was found that it could be recovered from the solution by adsorption on a column of " florisol." Evidence was also accumulated that its production was favoured by conditions leading to oxidation in the light. Finally, as relatively large amounts of cell material were formed, efforts were made to extract from this source materials showing antibacterial properties. Although the fresh extracts were not active in this respect, they became so on exposure to air and light, and a similar result was obtained when the dried algal cells were finely ground and exposed to air and light. By methods of this type it was shown that the production of the active material was associated with the photo-oxidation of the unsaturated fatty acids which are produced by *Chlorella* cells. Such photo-oxidations may yield a variety of products of which more than one may be antibacterial. Here, however, attention was focused mainly on one aspect of the problem, for it was found that the long-chain unsaturated acids naturally present in the cell lipids tended to split into chains of medium length containing 10 to 12 carbon atoms. It was these that were found to have definite antibacterial properties.

The formation of antibacterial substances through photo-oxidation is by no means confined to the lipid extracts of *Chlorella*. The same effect was found to occur in the lipid extracts of a variety of green plants. Moreover, the unsaturated fatty acids of various commercial fats and oils, such as coconut, maize, olive and raisin seed, also develop antibacterial properties on photoxidation. This is no doubt also the source of the antibacterial substances obtained by E. Uroma and O. E. Virtanen (*Ann. Med. exp. et Biol. Fenniæ*, **25**, 36, 1947) from yeast extracts as these included a mixture of unsaturated fatty acids.

Examination of the antibacterial properties of a series of acids

showed that capric (C_{10}) and lauric (C_{12}) acids were specially important. It will be noted that this matter is complex, as it hinges upon solubility (which diminishes in the higher homologues), hydrogen-ion concentration, ionisation and many other factors.

An adequate source of these acids was found in the seed fats of the Californian laurel (*Umbellaria californica*). The nuts of this plant readily yield a fat containing about 35 per cent. capric acid and 60 per cent. lauric acid. The antibacterial tests throughout were *in vitro* tests carried out in bacterial cultures. The effect of most of the substances on the germination of mustard seeds was roughly parallel to their inhibition of the growth of *Staphylococcus aureus*, the usual test material. When an attempt was made to test the laurel-nut preparations on diseased animals, the results were disappointing, as no significant results were obtained on animals infected with *Myobacterium tuberculosis* or *Salmonella enteritidis*.

The complexity of this problem will readily be realised when it is recalled that probably most cells contain long-chain unsaturated fatty acids in some form or other, especially types like oleic, linoleic and linolenic acids. These commonly have a double action, being growth stimulators at one concentration and inhibitors at another. This problem has received attention by M. R. Pollock in the recently published Symposium No. III, *Selective Toxicity and Antibiotics* (1949) published by the Society for Experimental Biology. This volume includes 22 papers which contain a wealth of information upon recent developments in this field. Perhaps of most general interest are a paper by H. N. Rydon on the design of bacterial inhibitors as modelled on essential metabolites, and another on chemotherapy from the point of view of the organic chemist by W. A. Sexton. C. N. Hinshelwood discusses the adaptation of bacteria to resist drug action and there are papers also by G. E. Blackman and his collaborators on the effects of phytocidal substances on a variety of higher plants.

PLANT PHYSIOLOGY. By Professor Walter Stiles, Sc.D., F.R.S., The University, Birmingham.

Respiration.—In the study of respiration it is often very desirable to determine both the oxygen absorbed and the carbon dioxide evolved by the tissue under examination. An apparatus enabling this to be done has been described by G. F. Asprey ("An Apparatus for following the Course of Gaseous Exchange by Living Tissue," *Proc. Roy. Soc. Edinburgh*, Ser. B, **63**, 163–78, 1948). Two well-known principles are combined in the apparatus. To determine the carbon dioxide evolved this is absorbed in a solution of barium

hydroxide, the change in electrical conductivity of which gives a measure of carbon dioxide absorbed, while the change in pressure registered by a manometer attached to the respiration chamber enables a simultaneous determination of the oxygen consumed. With the use of 20 ml. of 0·02N barium hydroxide and a respiration chamber with a capacity of 250 ml., quantities as small as 6·8 μg. of oxygen and 8·2 μg. of carbon dioxide could be measured. Increased sensitivity could be obtained by using smaller respiration vessels and smaller quantities of, and more dilute, barium hydroxide solution.

A new pattern microrespirometer of the differential manometer type has been described by H. Stern and P. L. Kirk (" A versatile Microrespirometer for Routine Use," *J. Gen. Physiol.*, **31**, 239–42, 1948). The two chambers of the instrument were drilled in a duralumin block and lined with a coat of lacquer. The block was covered by a removable plate of brass through which the ends of the capillary manometer tube passed, the tube being sealed to the plate with Khotinsky cement. The plate could then be clamped firmly to the block with the ends of the manometer tube in each chamber, the seal of each chamber being made with a rubber gasket. A hole was drilled through the side of the block into each chamber and was provided with a needle valve so as to allow adjustment of the kerosene used in the capillary. With this instrument good results could be obtained with as little as 3 to 4 mg. of plant tissue.

J. E. Mitchell, R. H. Burris and A. J. Riker have examined the effect of a number of growth-regulating and allied substances on respiration (" Inhibition of Respiration in Plant Tissues by Callus Stimulating Substances and Related Chemicals," *Amer. J. Bot.*, **36**, 368–78, 1949). A number of tissues including carrot petiole, bean and maize stems and roots, tomato stems and roots, and tomato crown gall were tested with indole-3-acetic acid and 2,4-dichlorophenoxyacetic acid in a concentration of 0·002M. In every instance the growth-regulating substance brought about a reduction in respiration rate. Slices of tomato stem were tested with a wider range of substances but with a similar result in every instance. The substances most effective in bringing about a fall in respiratory activity were those with an aromatic ring and free carboxyl group. Substances similar in constitution to growth regulators but without their effect on growth, such as benzoic, salicylic and nicotinic acids had a similar effect on respiration. The effect of indole-3-acetic acid was greatest at pH 5 and was reduced with increasing pH up to pH 6 or higher. The respiratory quotient was not affected by indole-3-acetic acid.

The effect of lowered oxygen tension on the inhibitory effect of indole-3-acetic acid was also examined. In control experiments without this substance it was found that lowering the oxygen concentration from 20 per cent. to 5 per cent. resulted in a lowering of the respiration rate. The inhibitory effect of indole-3-acetic acid was found to be much reduced in lower oxygen tensions, and its activity appeared to be proportional to the oxygen pressure. The authors suggested that this indicated that the system inhibited by growth regulators was also limited by low oxygen tension. In view of the part supposed to be played by various oxidising enzyme systems in respiration, it is interesting to find that cytochrome oxidase, ascorbic acid oxidase, catechol oxidase and glycollic oxidase, all appeared to be unaffected by indole-3-acetic acid, naphthalene-acetic acid and 2,4-dichlorophenoxyacetic acid.

As regards the effect of concentration of the growth-regulator, Mitchell, Burris and Riker found that with slices of tomato stem the reduction of respiration increased with increase in concentration. With bean roots the published graphs indicate that with 2,4-dichloro-phenoxyacetic acid in a concentration as low as $10^{-6}M$ the respiration rate was about 10 per cent. higher than that of the untreated control. From this high rate there was a continuous falling off until in a concentration of $10^{-2}M$ the respiration rate was only about 34 per cent. of that of the control.

The effect of 2,4-dichlorophenoxyacetic acid on the respiration of seedlings of wheat and mustard had previously been examined by D. L. Taylor ("Effects of 2,4-Dichlorophenoxyacetic Acid on Gas Exchange of Wheat and Mustard Seedlings," *Bot. Gaz.*, **109**, 162–76, 1947). In concentrations of the growth regulator ranging from 0·25 to 10 parts per million it was found there was a progressive decrease in both oxygen uptake and carbon dioxide evolution with increasing concentration. Somewhat different results were obtained with tissues of the oat coleoptile and garden pea stem, examined by Sally Kelly and G. S. Avery, Jr. ("The Effect of 2,4-Dichlorophen-oxyacetic Acid and other Physiologically Active Substances on Respiration," *Amer. J. Bot.*, **36**, 421–6, 1949). These authors found that in concentrations from 0·3 to 200 mg. per litre (or parts per million), 2,4-dichlorophenoxyacetic acid brought about an increase in respiration rate of oat coleoptiles above that of the control with increase in concentration, but that at higher con-centrations, for example, with a concentration of 1000 mg. per litre, the respiration rate was definitely reduced. With pea stems it was found that the stimulatory effect was produced by concentrations between 0·0001 and 10 mg. per litre, the concentration required to

produce an 18 to 20 per cent. increase in respiration rate over the control being only about one-thousandth of that required for oat coleoptiles. Dinitrocresol and dinitrophenol were found to have a greater effect than 2,4-dichlorophenoxyacetic acid in increasing the respiration of oat coleoptiles, and inhibition was brought about in lower concentration.

Not a great deal is known of the effect of oxygen concentration on the intensity of respiration. This question has now been examined with lemons by J. B. Biale and R. E. Young (" Critical Oxygen Concentrations for the Respiration of Lemons," *Amer. J. Bot.*, **34**, 301–9, 1947). A wide range of oxygen concentrations between 0·02 and 99·2 per cent. were used in their experiments. They found the course of respiration, as determined by carbon dioxide evolution, was very markedly affected by the oxygen concentration of the environment. In air over a long period, up to three months or a little longer, the respiration rate gradually fell. With oxygen concentrations higher than that of air, the respiration rate rose to a maximum and then fell, the rates being consistently higher than those of lemons in air. With oxygen concentrations lower than that of air the respiratory activity declined with falling oxygen concentration until it reached a minimum at a critical oxygen concentration which varied with different fruit samples, but which generally lay within the limits of 0·5 and 5·0 per cent. With further lowering of the oxygen concentration below this critical value the respiratory activity increased. The lowest respiratory quotient (0·66) was found with 5·3 and 11 per cent. oxygen ; with lower oxygen concentrations the quotient rose sharply, and with higher oxygen concentrations more gradually, but it was generally considerably below unity, although a value of 1·08 was found with 0·54 per cent. oxygen immediately after transfer from air. The longest storage life of lemons was found to occur in 5 per cent. oxygen.

An interesting paper on the products of anaerobic respiration has been published by Jean W. Phillips (" Studies on Fermentation in Rice and Barley," *Amer. J. Bot.*, **34**, 62–72, 1947). Although it is very generally supposed that the products of anaerobic respiration are equimolecular quantities of alcohol and carbon dioxide, yet the ratio alcohol/carbon dioxide is generally less than unity and no explanation is forthcoming of the origin of the extra carbon dioxide. Miss Phillips measured the amounts of carbon dioxide, alcohol and acetaldehyde produced by barley seedlings after various periods in nitrogen and found that after about the first 9 hours the rate of alcohol and aldehyde production together was not much different from the rate of carbon dioxide production, although the latter was

usually a little higher. During the first few hours of anaerobiosis, however, the rate of production of alcohol + acetaldehyde was very much lower than that of carbon dioxide ; thus during the first 3·5 hours the ratio of alcohol + aldehyde to carbon dioxide production was only 0·33. It may be noted that the aldehyde produced always amounted to about 1 per cent. of the amount of alcohol formed.

Some of the carbon dioxide formed during the first few hours of anaerobiosis might be accounted for as a loss of bound carbon dioxide from the cells, which would be released if an acid were produced in anaerobic respiration. Miss Phillips found that some lactic acid was indeed produced during the first six hours in nitrogen, as well as some unidentified volatile and non-volatile acids, but the amount of carbon dioxide which these might release from combination in the tissues was calculated to be less than the total amount unrelated to alcohol and aldehyde.

No difference was found in the ratio of alcohol to carbon dioxide produced in germinated grain, roots or shoots.

A marked fermentation was observed in detached barley leaves in air, respiratory quotients higher than unity being obtained. There was, however, very little anaerobic production of alcohol in older leaves ; in one experiment, for example, the same amount of alcohol was produced in presence of air as in its absence. Miss Phillips considered the aerobic fermentation was probably due to disturbed water relations in detached leaves, since alcohol was not formed by leaves left with their cut ends in water or nutrient solutions, nor by intact plants.

H. Stern and P. L. Kirk, whose new pattern microrespirometer has been mentioned earlier, have recorded some results obtained by the use of their instrument with the anthers of *Trillium erectum* (" The Oxygen Consumption of the Microspores of Trillium in Relation to the Mitotic Cycle," *J. Gen. Physiol.*, **31**, 243–8, 1948). Single anthers were used in the respiration chambers. The course of respiration was followed during the development of the microspores, the stage of nuclear division being examined by means of aceto-carmine smears. It was found that after the production of the one-celled microspores the oxygen consumption tended to rise. Immediately before the following mitotic division the oxygen consumption fell rapidly and remained at a low value during the active division of the nucleus. It would thus appear that oxygen consumption should not be regarded as a measure of respiratory activity, since it is unlikely that the energy requirements of cells would fall during cell division.

Miss F. M. V. Hackney has continued her researches on the respiration of apples. In a paper dealing with the respiration of thin slices of apple tissue (" Studies in the Metabolism of Apples. VI. Preliminary Investigations on the Respiration of Sliced Apple Tissue," *Proc. Linnean Soc. N.S.W.*, **70**, 333–45, 1947) she has recorded a number of interesting observations. It was found that slices of apple tissue, unlike those of storage organs such as potato, carrot and beetroot, rapidly lost both water and dissolved substances when surrounded by distilled water. These losses appeared to be due to rapid absorption of water bringing about disorganisation of cells, a view supported by the fact that in solutions isotonic with the cell sap the losses were very small or negligible. However, the respiration rate of discs of tissue washed overnight in $0.25M$ calcium chloride solution was no greater than that of discs similarly washed in distilled water.

The respiration of thin discs of apple flesh which had been washed in distilled water and then placed in the respiration chamber of a Warburg manometer fell rapidly, reaching a low steady level after two or three hours. This level was lower the longer the period of preliminary washing up to a period of 20 minutes, but did not fall appreciably with longer periods of washing. Thus with no preliminary washing the respiration rate was 16·5 cu. mm. per g. initial weight per hour, and with a washing period of 20 minutes or longer about 5·0 cu. mm. per g. initial weight per hour. This decrease in respiration rate with prolonged washing would appear to be due to the loss of material from the tissue already mentioned. Moreover, no significant difference was observed in the respiration rate of tissue washed for different lengths of time in calcium chloride solution isotonic with the cell sap. There was, however, a slight initial fall in respiration rate when the tissue discs were immersed in calcium chloride solution, so that the drift of respiration would appear to have been determined by some factor in addition to the disorganisation of some of the cells.

In contrast to results obtained with tissues of roots and tubers Miss Hackney found no indication of a reduction in respiration rate per unit weight of tissue with increase of disc thickness up to 2 mm.

Unlike the flesh, the skin of the apple increased in weight as a result of washing in water, owing to absorption of the latter.

Miss Hackney compared the respiratory activity of the skin of the apple and of thin slices taken from different regions of the apple, namely, from the surface to a depth of 3 mm., from 4 to 8 mm. below the skin, from 8 to 14 mm. below the skin, and from a deeper depth than 14 mm. While the skin respired at a markedly higher

rate than the flesh, no significant difference between the respiration rates of the flesh from the different regions could be observed. Based on fresh weight, the skin was found to respire at about fourteen times that of the flesh, while based on dry weight the respiratory activity of the skin was about five times that of the flesh. This difference in the respiratory activity of skin and flesh was regarded by Miss Hackney as probably related to the greater number of cells per unit weight in the skin.

In two later papers Miss Hackney has dealt with oxidising systems in apples in relation to respiration. The first of these contributions concerned catechol or polyphenol oxidase (" Studies in the Metabolism of Apples. VII. A Study of the Polyphenolase System in Apples," *Proc. Linnean Soc. N.S.W.*, **73**, 439-54, 1949). It was found that when various substrates of catechol oxidase such as protocatechuic acid, catechol and *p*-cresol were added to the medium surrounding thin slices of apple tissue there was an increase in the rate of oxygen uptake and sometimes of the rate of carbon dioxide evolution. In experiments in which tissue from immature apples was used more oxygen was consumed than could be accounted for by the quantity of protocatechuic acid added. This was held to suggest that this substance could act as a respiratory catalyst. Resorcinol and potassium cyanide, both of which were known inhibitors of catechol oxidase from potato, were found to inhibit the respiration of apple tissue when they were supplied in suitable concentrations. They were also found to inhibit the action of a catechol oxidase preparation obtained from apple tissue. Analysis of experimental data showed that resorcinol acted as a competitive inhibitor, the affinity of the enzyme for resorcinol being very much greater than its affinity for catechol. These various findings all indicated that catechol oxidase was concerned in the mechanism of respiration in apple tissues.

The second of the contributions on enzyme systems in the respiration of apples dealt with ascorbic acid oxidase. (" Studies in the Metabolism of Apples. VIII. Ascorbic Acid Oxidase in Apples," *Proc. Linnean Soc. N.S.W.*, **73**, 455-65, 1949). Results obtained in this work were very similar to those obtained in respect to catechol oxidase. Thus both the oxygen consumed and carbon dioxide given out by slices of apple flesh were increased by the addition of ascorbic acid in low concentrations, the oxygen absorbed being considerably more than could be accounted for by the quantity of acid added, a finding which suggested that ascorbic acid acted as a respiratory catalyst.

When ascorbic acid and protocatechuic acid were added together

to slices of apple flesh it was found that their effects were additive as regards the extra oxygen consumed, thus suggesting that the oxidisation of the two substances was effected by different mechanisms. The general conclusion was drawn that, while part of the respiratory processes of the apple involves catechol oxidase, part is carried on through the action of ascorbic acid oxidase.

ENTOMOLOGY. By A. D. LEES, M.A., Ph.D., Agricultural Research Council Unit of Insect Physiology, Cambridge.

PLASTRON RESPIRATION.—Many aquatic insects possessing an open tracheal system carry air-stores, either in the form of bubbles entangled in the pubescence or as gas contained in special sub-elytral chambers. That the air-store could subserve a second, and more important, function, that of a " physical gill " for extracting oxygen from solution in water, was first recognised by Ege who demonstrated that, by this means alone, small, inactive species were rendered practically independent of visits to the surface.

The accepted interpretation of the " gill " mechanism (which is summarised in the papers cited below) is as follows. The bubble of air at first contains both oxygen and nitrogen. As oxygen is respired by the insect, the tension of oxygen in the bubble falls and that of nitrogen rises ; and this process in turn results in the diffusion of oxygen into the bubble from the surrounding water while nitrogen diffuses out. The efficiency of the " gill " is further enhanced by the fact that the " invasion coefficient " of oxygen between water and air is greater than that of nitrogen. Although the original concept of the " invasion coefficient " as a physical entity has proved to be spurious, it has been retained as a useful expression describing the passage of gas across the thin stationary layer of water at the surface of the bubble. For, since oxygen is rather more than twice as soluble in water as nitrogen, the permeability of the surface layer to oxygen will be proportionately greater.

For the insect the primary disadvantage of this fortuitous mechanism is that the " gill " only functions as long as the bubble contains some nitrogen. The volume of the air-store is, of course, constantly diminishing, and, when all the nitrogen has been lost and the remaining oxygen used up, the insect must return to the surface to renew the air supply.

A few insects have evolved a structure—which Brocher named the plastron—capable of retaining permanently an extremely thin air film of constant volume. Since the film can be maintained against considerable pressure differences, these insects have become completely independent of atmospheric air. Prior to the recent

work of W. H. Thorpe and D. J. Crisp little was known of the respiratory mechanisms of these remarkable insects, many of which are rare. Their " Studies on Plastron Respiration " have touched on all aspects of this subject. The first three papers in the series (1947, *J. exp. Biol.*, **24**, 227, 270 and 310) are devoted to *Aphelocheirus* and deal with the mechanism of plastron retention, the respiratory efficiency of the plastron and with the orientation responses and pressure receptors. The physical principles underlying the water-protective properties of insect hairs are examined in a separate article (Crisp and Thorpe, 1948, *Trans. Faraday Soc.*, No. 3, 210).

Aphelocheirus æstivalis (Hemiptera-Heteroptera) is a large and active predaceous insect living in rapidly flowing streams at moderate depths. It is perhaps the most perfectly adapted plastron insect known. In the adult the plastron consists of a " pile " of minute vertical hairs, over 2 million per sq. mm., arranged with the utmost regularity. The continuous air film retained beneath the hair pile is visible as a luminous grey sheen on the under surface. The highly modified abdominal spiracles, also protected by plastron hairs, communicate freely with the plastron air space.

The respiratory function of the plastron could be demonstrated by " painting out " the air film with a wetting agent (thereby reducing the contact angle at the hair-water interface). Such insects quickly show signs of asphyxia. On the other hand, the plastron is highly resistant to pressure changes. With bubble-carrying insects the gill mechanism fails in oxygen-saturated water, for if the air-store lacks nitrogen no pressure differences can be established across the interface. In *Aphelocheirus* the surface forces are entirely adequate to maintain the interface against pressure differences of this order ; and an excess hydrostatic pressure of 3–5 atmospheres has to be applied before the abdominal sheen disappears—an indication that water has entered the plastron.

The authors develop a highly ingenious theory regarding the properties of different arrangements of hydrofuge hairs. They show that the two requirements of resistance to wetting and resistance to mechanical collapse of the hair pile conflict to some extent with the need for a large gas-water interface for respiratory exchanges. A system of vertical rod-shaped hairs would permit maximum gas exchange but would offer little resistance to wetting ; a system of horizontal hairs would provide greater pressure resistance while reducing the diffusion paths. A compromise seems to have been reached in *Aphelocheirus* for, although the shafts of the plastron hairs are arranged vertically, their tips are neatly bent over almost

at right-angles to the shaft. It would be expected on theoretical grounds also that the smaller the dimensions of the free spaces between the airs the greater would be the water protection. This could be achieved by reducing the size of the hairs. But reduction below a certain critical size would result in the emergence of a further limiting factor, the structural rigidity of the hair material. It would seem that in their shape, size and arrangement the plastron hairs of *Aphelocheirus* must approach the condition best suited for reconciling these opposing requirements.

The efficiency of the plastron as a respiratory organ is not greater than can be accounted for by simple gaseous diffusion. The main diffusion resistances are shown to occur at the plastron-water interface and at the junction of the tracheal endings with the tissues. Nevertheless, the total resistance amounts to little more than 3 per cent. atm. when the insect is at rest.

The 5th instar nymph has no plastron, obtaining all the oxygen required by cutaneous respiration. The cuticle is more permeable to oxygen and the nymph itself is much less active than the adult. From their respirometer experiments Thorpe and Crisp deduce that if the adult insect depended only on cutaneous respiration, an oxygen tension of 20 per cent. atm. would be required to maintain basal respiration and 130 per cent. atm. to support vigorous movement. Some supplementary respiratory mechanism clearly becomes a necessity in the adult. With the plastron in operation the values for the oxygen tensions required at rest and during activity are reduced to 3 and 20 per cent. atm. respectively.

The authors describe how the ecology and behaviour of the insect is bound up with the acquisition of the plastron. Since, in contrast to the air-stores of bubble-carrying insects, the plastron gas is of negligible volume, *Aphelocheirus* is heavier than water and has become a true bottom-living predator. The insect can colonise rapidly-flowing streams where, if it had to return to the surface for air, it would risk being carried away by the current. At the same time the species is, of course, restricted to turbulent, well-aerated waters.

Aphelocheirus is also well provided with proprioceptors, which doubtless serve to prevent sudden uncontrolled movements into deep waters of low oxygen tension. Tactile trichoid sensilla probably register the direction of currents when the insect is crawling on the bottom. The dorsal light reaction enables it to maintain an even keel if the illumination is adequate. But, in addition, *Aphelocheirus* possesses a pair of specialised pressure receptors situated on the 2nd abdominal segment. These consist of patches of recumbent

hydrofuge hairs interspersed with innervated tactile sensilla. The hairs hold a gas film continuous with the plastron air space. Any pressure change, whether uniform or differential, will alter the angle of inclination of the hairs, thereby stimulating the tactile sensilla. By means of these organs *Aphelocheirus* can maintain an even keel even in darkness ; and it responds to a general pressure increase by swimming vigorously upwards.

The superficially similar pressure receptors in *Nepa* have also been re-examined. In this insect there are three pairs of organs, located on the 3rd, 4th and 5th sterna, each consisting of a number of over-lapping scale-like processes which when depressed touch the sensitive endings of certain specialised tactile cells. The air spaces beneath the scale-membrane of each organ intercommunicate by means of the tracheal system. Baunacke's original interpretation of their function was found to be essentially correct, for, as their response is seemingly of an all-or-nothing character, the receptors could not serve, as in *Aphelocheirus*, to register general pressure changes. If, however, the body axis is inclined to the horizontal, air pressure in the system will slightly distend the scale-membrane of the higher organ while tending to collapse that of the lower. Such an organ, which functions as a sensitive differential manometer, would record relative changes in the body position with extreme precision and is evidently well adapted to the mode of life of the insect as it climbs slowly on water-weed and other submerged objects.

Among the Coleoptera Thorpe and Crisp (1949. *J. exp. Biol.*, **26**, 219) have described a remarkable range of plastron-bearing insects, including members of the Dryopoidea (Elmidæ), Donaciine beetles of the genus *Hæmonia* and the weevil *Phytobius velatus*. They group aquatic insects with hydrofuge hairs into four categories. The first, which includes those with the most perfect structural and functional adaptations, possess an extremely fine hair-pile capable of withstand-ing a pressure of at least 2 atm. without wetting. The plastron functions solely as a gill and is too thin to afford a reserve of oxygen. *Aphelocheirus*, some Dryopoidea and *Phytobius* are placed in this group. In the latter insect the plastron consists of a vestiture of overlapping scales beset with plastron hairs. These structures recall the furry club-shaped hairs borne on the dorsal plastron areas of the aquatic larvæ of the Arctiid genus *Palustra*, described by P. Portier in *La Biologie des Lépidoptères* (1949, *Encyclopédie Entomologique*, *Sér. A*, **23**, 638 pp.)

The second group includes *Hæmonia* and Elmids of the genera *Elmis* and *Riolus*. Here the plastron hairs are a little larger and less densely arranged and can withstand an excess pressure of only

0·5-2·0 atm. The condition of the Elmidæ is particularly interesting, for, although the plastron is functionally perfect in the sense that the insects need never come to the surface, it is not perfect structurally and so needs to be kept in good condition by the attentions of the insects themselves. The plastron hairs are relatively long, flexible and inclined to the horizontal. Any increase in external pressure causes the hairs to bend over and assume more closely the horizontal arrangement that is theoretically best adapted as a water-protective device. At the same time, however, there is a tendency for the outer gas layer (the " macro-plastron ") to be lost by solution and for the hairs to become matted together, leaving lacunæ in the plastron through which water can penetrate. The insect avoids this contingency by persistently grooming the main plastron areas by means of plastron " brushes " located on the inner sides of the femora. Elmids are also often seen capturing small bubbles of oxygen or air adhering to plants and smearing them over their bodies. By such " plastron replacement activities " the parallel alignment of the plastron hairs is preserved and the macro-plastron gas is kept replenished.

In the third group, which includes a further series of Dryopoidea and the Hydrophilid beetles, the plastron hairs are still more sparse and the penetration pressure only 0·5 atm. In *Hydrophilus* itself there is a double array of small and large plastron hairs ; the latter serve to retain the macro-plastron gas layer, which is of so large a volume that it may be of less importance as a gill than as an air-store. In the smaller Hydrophilidæ, the volume of gas so increases the buoyancy that the insect bobs to the surface unless it is actively swimming or clinging to some submerged object.

The fourth group comprises moisture-loving or riparian insects. They have no plastron, but their hydrofuge hairs serve to prevent wetting when the insect enters the water to lay eggs or accidentally falls in the water. The comparison of related riparian and plastron-bearing species (*e.g. Donacia* and *Hæmonia*) affords an interesting insight into the probable course of evolution. In *Donacia* the raw materials for evolution are already present. Only comparatively small modifications in the density, arrangement and shape of the hairs are needed to transform quite an ordinary equipment of hydrofuge hairs into the perfected plastron.

INSECT FLIGHT AND THE UTILISATION OF RESERVE SUBSTANCES.—The rapidity of the wing movements in many insects has long attracted attention. Frequencies above 15 cycles per sec. generate a " flight-tone " which falls within the human acoustic range. The possession of a sense of absolute musical pitch, which

was supplemented by confirmatory measurements, has enabled O. Sotavalta (1947, *Acta Ent. Fennica*, **4**, 1) to determine the flight-tone in a range of insects. In some of the smallest midges (Chironomidæ) the flight-tone corresponds to a wing-stroke frequency of over 1000 cycles per sec., and values of 100–300 are commonplace. This compares with contractile rates of 65 for the wing of the humming bird and 20 for the scratching reflex in the mouse. Owing perhaps to the small wing areas of most insects, air damping was found to have little or no effect on the wing-beat frequency, which remained constant when the insect was exposed to a partial vacuum. Virtually all the energy expended during these astonishingly rapid muscle contractions is therefore used in moving the wings up and down rather than in overcoming air resistance.

Questions of energy consumption and the nature of the reserve substances utilised during flight have been studied particularly closely in *Drosophila*. L. E. Chadwick and D. Gilmour (1940, *Physiol. Zool.*, **13**, 398) found that in *D. repleta*, which has a wing-beat frequency of 180 cycles per sec., the oxygen consumption during flight rose to some 13 times the resting level. C. M. Williams, L. A. Barness and W. H. Sawyer (1943, *Biol. Bull.*, **84**, 263), using *D. funebris*, then established that glycogen was used during flight. The mature fly contained 6 per cent. of glycogen by weight and progressive changes in the glycogen content during adult life were reflected in the duration of flight before a state of exhaustion supervened. And Chadwick (1947, *Biol. Bull.*, **93**, 229) later demonstrated that in two other species the R.Q. during flight was close to 1·0.

More recently V. B. Wigglesworth (1949, *J. exp. Biol.*, **26**, 150), working with *D. melanogaster*, has provided a histological picture of the distribution of the reserve substances and of their mobilisation during flight. The principal reserve substance in the mature fly—glycogen—forms dense deposits in the fat body and haltere knobs and is distributed in smaller quantities at the surface of the muscle bundles, around the muscle insertions and elsewhere. The fairly extensive reserves of fat are confined to the fat body and mid-gut cells.

When the fly is walking round its container or is undergoing starvation, glycogen and fat are utilised concurrently. But this is not so during flight. Indeed, in exhausted insects, which have flown continuously for 4–5 hours, the fat deposits are virtually untouched, although glycogen, of course, is greatly depleted. Flight can be resumed temporarily after the insect has been allowed a brief resting period for the mobilisation of fresh reserves.

Flies depleted of all readily available reserves by successive

" flights to exhaustion " proved to be excellent material for investigating certain other questions. Thus the rate of consumption of carbohydrate during flight could be estimated by feeding the exhausted fly with a measured volume of glucose solution at the tip of a waxed pipette and timing the duration of flight. The recovery time and subsequent flight behaviour was so consistent that this technique could also be used for determining the value of different substances as sources of energy. It is a striking fact that glucose can restore the capacity for flight within 45 seconds of the moment when the solution touches the proboscis. Fructose and sucrose become effective rather more slowly, while other sugars, such as galactose, enable the insect to fly but fail to support continuous flight.

Wigglesworth suggests that exhaustion supervenes when the reserves are reduced to such a low level that mobilisation fails to keep pace with consumption. Although the slow metabolism of fats in *Drosophila* evidently precludes their use as reserves during flight, fats are often the principal fuel in other insects, particularly in those making sustained migratory flights. In the beet leafhopper, for example, R. A. Fulton and V. E. Romney (1940, *J. agric. Res.*, **61**, 737) were able to base their estimates of the distance individual insects had flown from the breeding areas in Utah and Arizona on analysis of the fat content. This work on *Eutettix tenellus* has been continued by W. C. Cook (1944, *Ecology*, **25**, 327). The reserves of fat in two British species of migratory moths were determined by C. B. Williams (1945, *Proc. Roy. Ent. Soc. Lond.*, A, **20**, 6). And G. Beall (1948, *Ecology*, **29**, 80) has published fat analyses for the Monarch butterfly, *Danaus plexippus*. The latter insect affords one of the most spectacular examples of insect migration, flying during the autumn from the northern United States and Canada to subtropical regions, particularly Florida and California. The young butterflies start their southerly migration with a fat content equal to 125 per cent. of the lean weight. This is reduced to 30 per cent. in butterflies lost over Lake Erie ; and in new arrivals at the place of overwintering, it may fall as low as 2 per cent. Fat is again laid down during the winter months in preparation for the return migration in spring.

NOTES

"Astronomy and Navigation" (M. W. O.)

In *Occasional Notes of the Royal Astronomical Society*, No. 13, the Superintendent of the Nautical Almanac Office, Mr. D. H. Sadler, writes on " Astronomy and Navigation." In the author's words, " the main object of this article is to follow recent progress in the technique and application of astronomical navigation, developing a central theme of the constant interdependence of astronomy and navigation." A history of the growth of astronomical navigation includes a discussion of fundamental problems, and emphasises the significant influence which the Royal Astronomical Society has exerted in moulding the form and content of the various editions of the Nautical Almanac. It is only recently that this rôle of adviser has fallen to another body, the newly-formed Institute of Navigation, under whose auspices the practical navigator (whose influence in the past is noted only for its absence) will add the weight of his experience to that of the astronomer in framing future policy. The second part of Mr. Sadler's essay, which deals with modern developments, shows that he is well aware of the claims of radio navigation, but believes that much important work remains to be done in the astronomical sphere in the solution of navigational problems and the simplification of tables and procedure. Part III, " The Future," speculates upon the influence of the rising science of astronautics on astronomical navigation, on the one hand by contributing in the " Earth Satellite Vehicle " an almost ideal object for navigation observations, and on the other hand by bringing its own problems and difficulties of " interplanetary navigation."

" Astronomy and Navigation " is published and sold by the Royal Astronomical Society, with 17 pages, 3 diagrams and 2 plates, price 3*s*. 6*d*. net.

National Museum of Wales Annual Report, 1948-49 (A. B.)

The past year has seen the introduction of the new scheme for a museum schools service, referred to in our note of April 1949. A five-year initial plan is envisaged and the first two appointments have been made, one in association with the Department of Archæo-

logy and the other with the Department of Geology. As provision will need to be made for upwards of 300 secondary schools, it will be apparent that some time must elapse before the new service in its initial stages attains to useful proportions. There is no doubt that eventually the scheme will play a very important part in the educational life of Wales.

The Welsh Folk Museum at St. Fagans, opened in July 1948, has been enriched by the addition to its collections of over 1800 exhibits during the year under review. Outstanding gifts include a valuable collection of Welsh embroidery and lace patterns, a rare bracket clock, musical instruments, a late seventeenth-century bread-crate and an ark-lid chest of early eighteenth-century date. Welsh rural economy is illustrated by typical wagons, an ox-wain and a large collection of carpenter's tools.

A new scheme has been launched for the recording and preservation *in situ* of early machines and plant used in the " Special Industries of Wales," and as a beginning enquiries are being made by the Department of Geology regarding the slate and tinplate industries. Some excellent models of fungi have been made for the Botany Department, which has also received an important bequest from the late Miss Eleanor Vachell of the valuable herbarium formed by the late Dr. C. T. Vachell and herself. This collection is especially rich in material from the county of Glamorgan.

A large collection of shells of fresh-water mussels has been added to the Zoological Collections by a gift from Mr. J. R. le B. Tomlin, including a series of *Lumbricillus reynoldsoni* from the Menai Straits. On the Archæological side much work has been done on the reorganisation of the Roman Gallery, and a series of interesting carved and inscribed stones from Welsh localities has been arranged. Work has also been done on the preservation of existing material, an all-important and essential function of museums on which too much emphasis cannot be laid. Many valuable additions have been made to the Department of Art and to the Library.

The National Museum of Wales is now included in the terms of reference of the Standing Commission on Museums and Galleries and the Treasury have also authorised the appointment of one additional member of the Commission on the joint nomination of the National Museum of Wales and the National Library of Wales.

Association of British Chemical Manufacturers' Safety Conference (W. P.)

In October last year a Conference on Chemical Works Safety was sponsored by the Association of British Chemical Manufacturers,

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and organised for them by the Industrial Division of the Royal Society for the Prevention of Accidents.

In the Proceedings which are being published by the Association, T. Senior has discussed the training of workers in the use of breathing apparatus, and Dr. A. J. Amor has presented in the form of useful tables recorded data on the toxicity of a wide range of organic liquids, while S. W. Richards has collected information regarding explosion risks and the electrical equipment and systems which can be safely used in the presence of dusts and vapours.

Non-Ferrous Metal Industry in Germany, 1939-45 (C. J. F.)

A survey * of German industry covering the field of non-ferrous metals, which is one of a series formerly known as B.I.O.S. Overall Reports, has been prepared by Prof. L. Aitchison and Dr. V. Kondic of Birmingham University. The survey summarises and forms a guide to the Allied investigations on the subject reported in the official C.I.O.S., B.I.O.S., F.I.A.T. and J.I.O.A. reports and in the F.D. and H.E.C. documents held by the T.I.D.U. Section of the Board of Trade. It is divided into four main parts, dealing respectively with light, base, rare and precious metals, and there is a fifth part dealing with miscellaneous items. The light metal and base metal parts are divided into sections on : smelting and refining ; casting ; wrought fabrication and finishing ; alloys (composition, structure, properties) and research ; and uses and applications. The rare metals have short general sections devoted to them and the precious metal part has sections on extraction and refining, alloys, and uses and applications. The miscellaneous part consists of a bibliography only.

At the end of each section or part is a comprehensive bibliography of the relevant reports and documents—it should be noted that very many of these, particularly of the less important documents, are not otherwise referred to in the survey. Two-thirds of the publication is taken up by these bibliographies.

The general conclusion drawn by the survey is that, on the whole, German practice was conventional and well known and that there were few outstanding developments. Improvements on the standard methods and equipment are noted, however, and reference is made to data on novel processes, including those tried out on the laboratory or pilot plant scale.

* *The Non-Ferrous Metal Industry in Germany during the period 1939-1945.* British Intelligence Objectives Sub-Committee Surveys, Report No. 23. [Pp. 198.] (H.M.S.O., 1949. 3s. 6d. net.)

Miscellanea

The New Year Honours List contained the names of the following scientists and others associated with scientific work : *Baron :* Dr. L. Haden Guest, M.P., secretary of the Leverhulme Research Fellowship Committee. *K.B.E. :* F. Brundrett, chief of the Royal Naval Scientific Service ; H. C. Papworth, vice-chancellor of the University of Travancore. *D.B.E. :* Prof. Olive Wheeler, professor of education and dean of the Faculty of Education in University College, Cardiff. *Knights :* Prof. A. L. Bowley, during 1919–36 professor of statistics in the University of London ; A. M. Bryan, chief inspector of mines, Ministry of Fuel and Power ; Philip Hendy, director of the National Gallery ; Dr. A. W. Pickard-Cambridge, deputy chairman of the Public Schools' Governing Bodies Association, during 1930-38 vice-chancellor of the University of Sheffield ; S. J. Saint, director of agriculture, Barbados ; Arthur Sims, for services to medicine and education in the British Commonwealth ; Prof. A. G. Tansley, chairman of the Nature Conservancy ; Dr. W. W. D. Thomson, professor of medicine, Queen's University, Belfast ; Prof. R. L. Turner, director of the School of Oriental and African Studies, University of London. *C.B. :* A. H. Gosling, director-general of the Forestry Commission ; S. S. Hall, director-general of technical development (air), Ministry of Supply ; Dr. O. H. Wansbrough-Jones, scientific adviser to the Army Council. *C.M.G. :* A. B. Killick, director of agriculture, Uganda ; W. H. Cocker, of Auckland, New Zealand, for outstanding services in university administration and adult education. *C.B.E. :* J. Anderson, chief scientist, H.M. Underwater Detection Establishment, Portland ; Mehmed Aziz, Anopheles Eradication Scheme, Cyprus ; O. G. S. Crawford, archæologist ; H. W. Dawes, president of the Royal College of Veterinary Surgeons ; A. N. Duckham, agricultural attaché at the British Embassy at Washington ; Prof. F. Hardy, professor of chemistry and soil science, Imperial College of Tropical Agriculture, Trinidad ; C. Harvey, director of agriculture, Fiji ; Dr. Franklin Kidd, director of food investigation, Department of Scientific and Industrial Research ; E. C. Lloyd, deputy chief veterinary officer, Ministry of Agriculture ; Miss Ida C. Mann, senior surgeon, Royal London Ophthalmic (Moorfields) Hospital ; Prof. J. W. Munro, professor of zoology and applied entomology in the Imperial College of Science and Technology, London ; F. M. Owner, chief engineer (Engine Division), Bristol Aeroplane Co., Ltd. ; Prof. F. G. Soper, Professor of chemistry in the University of Otago ; W. J. Spafford, lately director of agriculture, South Australia ; K. T. Spencer, deputy director of aircraft

research and development (technical), Ministry of Supply; Prof. A. M. Tyndall, chairman of the Executive Committee, National Physical Laboratory.

At the anniversary meeting of the Royal Society held on November 30 the following were elected as officers for the ensuing year : *President*, Sir Robert Robinson ; *Treasurer*, Sir Thomas Merton ; *Secretaries*, Sir Edward Salisbury and Sir David Brunt ; *Foreign Secretary*, Prof. E. D. Adrian.

The two Royal Medals of the Royal Society for 1949 were awarded to Sir George Thomson, for his distinguished contributions to many branches of atomic physics, and especially for his work in establishing the wave properties of the electron, and Prof. R. A. Peters, for his distinguished biochemical researches, in particular his investigations of the biochemical rôle of vitamin B_1 in tissue metabolism, and of the mechanism of the toxic action of lewisite and other arsenical compounds. The following medals were also awarded : Copley Medal to Prof. G. C. de Hevesy, for his distinguished work on the chemistry of radioactive elements and especially for his development of the radioactive tracer technique in the investigation of biological processes ; Davy Medal to Prof. A. R. Todd, for his structural and synthetic studies and achievements in organic and biochemistry, with special reference to vitamins B_1 and E and the naturally occurring nucleosides ; Sylvester Medal to Prof. L. J. Mordell, for his distinguished researches in pure mathematics, especially for discoveries in the theory of numbers ; Hughes Medal to Prof. C. F. Powell, for his distinguished work on the photography of particle tracks and in connection with the discovery of mesons and their transformation.

The Nobel Prize for Physics for 1949 was awarded to Prof. H. Yukawa, of Tokyo, visiting professor at Columbia University, New York, the Nobel Prize for Chemistry to Prof. W. F. Giauque, professor of chemistry in the University of California, and the Nobel Prize for Physiology and Medicine jointly to Prof. W. R. Hess, of Zürich, and Prof. A. E. Moniz, of Lisbon.

Other medals awarded include the medals of the Geological Society : Wollaston Medal to Dr. Norman L. Bowen, of the Geophysical Laboratory, Washington, Murchison Medal to Mr. Tom Eastwood, lately assistant director of H.M. Geological Survey, Lyell Medal to Prof. S. J. Shand ; Faraday Medal of the Institution of Electrical Engineers to Sir James Chadwick, F.R.S. ; Baker Gold Medal of the Institution of Civil Engineers to Major-General A. C. Fewtrell.

We have noted with great regret the announcements of the death of the following scientific workers during the quarter : Mr. J. E. Barnard, F.R.S., formerly head of the Department of Applied Optics, National Institute of Medical Research ; Prof. Alfred S. Barnes, formerly professor of electrical engineering in the University of Manchester ; Dr. Isaiah Bowman, lately president of Johns Hopkins University ; Mr. W. E. Copleston, C.S.I., formerly chief conservator of forests, Bombay ; Dr. Clifford Dobell, F.R.S., Protistologist to the Medical Research Council ; Dr. J. N. Keynes, Registrary Emeritus of the University of Cambridge ; Prof. René Maire, professor of botany in the University of Algiers ; Mr. J. F. Marshall, C.B.E., Director, British Mosquito Control Institute, Hayling Island ; Prof. Alexander Meek, emeritus professor of zoology in the University of Durham ; Prof. Stefan Meyer, formerly director of the Vienna Radium Institute ; Prof. W. H. Newton, professor of physiology in the University of Edinburgh ; Prof. T. Slater Price, O.B.E., F.R.S., emeritus professor of chemistry at the Heriot-Watt College, Edinburgh ; Dr. A. E. V. Richardson, C.M.G., lately chief executive officer of the Commonwealth Council for Scientific and Industrial Research, Australia.

A paper by R. J. Corruccini in the *Journal of Research* (August 1949), published by the National Bureau of Standards of the U.S.A., contains a discussion of the changes in the temperature scale, adopted in 1927 by the Seventh General Conference on Weights and Measures, made at the Ninth General Conference held in 1948. The most obvious are the change in the silver point (from 960·5° C. to 960·8° C.), in the Wien constant c_2 (from 1·432 to 1·438 cm. deg. C.), and the use of Planck's law for temperatures above the gold point. In addition it was agreed that the zero of the thermodynamic scale should be defined as 0·0100 deg. below the triple point of water. The range of temperature to be determined with the platinum resistance thermometer was altered slightly, *viz.* from the oxygen point ($-182\cdot970°$ C.) to the freezing-point of antimony (about 630·5° C.), instead of from $-190°$ C. to 660° C. These and other small changes produce an appreciable difference between the numerical values of temperatures above 630·5° C. when expressed on the 1948 and 1927 scales. They agree, of course, at the antimony and gold (1063° C.) points, which remain unaltered, but between these temperatures the 1948 scale gives higher numerics (the maximum difference being 0·43 deg. C. at 840° C.). Above the gold point the numerical values on the 1948 scale are lower than on the original scale ; the difference is 1·1 deg. C. at 1300° C., 6·4 deg. C.

at 2000° C., 20 deg. C. at 3000° C. and 43 deg. C. at 4000° C., which is about the highest temperature at which the Wien law formula, specified in the 1027 scale, is sufficiently accurate. Writing $c_2 = 1.438$ and using the Wien law instead of Planck's law makes a difference of less than 1 deg. C. in the evaluation of temperatures below 3500° C. At 4000° C. use of Wien's law gives a value 3·2 deg. C. above that calculated from Planck's law, while at 5000° C. the difference becomes 16·8 deg. C.

Two other papers in the August 1949 issue of the *Journal of Research* may be of general interest. One, by N. Bekkedahl, describes a relatively simple technique for volume dilatometry ; the other, by I. C. Gardner, deals with the entrance and exit pupils of telescopic systems.

The Tin Research Institute has published a booklet dealing with the composition, properties and uses of fusible alloys containing tin. First there are binary eutectics melting at temperatures between 221° C. (96·5% Sn, 3·5% Ag) and 117° C. (48% Sn, 52% In) ; next a group of alloys based on the ternary eutectic (Sn 15·5%, Bi 52·5%, Pb 32%), which itself melts at 96° C. ; and finally, in the " near eutectic " series, alloys based on the quaternary eutectic (Sn 13·1%, Bi 49·5%, Pb 27·3% and Cd 10·1%) which melts at 70° C. The ternary group includes Newton's and Rose's alloys and the quaternary Wood's and Lipowitz's alloys. The addition of gallium or indium to the quaternary alloys lowers their melting-point to a limit of about 47° C., or by the further addition of mercury to 38° C. The booklet gives details of the mechanical properties of many of the commercial alloys, *e.g.* Cerromatrix, used for locating and securing dies, punches, etc., in their mounts. This alloy melts at 103° C., has a tensile strength of 13,000 lb. wt. per sq. in., a Brinell hardness of 19, zero coefficient of thermal expansion between 54° C. and 103° C., and expands slightly on solidification. Cerrotru, a tin bismuth eutectic melting at 138° C., is used for metal patterns cast from a master pattern, since there is no sensible change in its volume on solidification. The booklet refers to many other uses of low melting-point alloys, *e.g.* sprinkler heads, glass-metal seals, fillers for tube bending, tempering baths and the metallisation of wood. It is obtainable, free of charge, from the Tin Research Institute, Fraser Road, Greenford, Middlesex, England, or 492 West Sixth Avenue, Columbus, 1, Ohio, U.S.A.

The Tin Research Institute publishes also a journal entitled *Tin and its Uses*. It is presumably the intention of the Institute that a new number should appear each month, but under present

conditions it appears only at irregular intervals. The issue for October 1949 contains a number of useful and well-illustrated articles concerned with the production of the metal and its application in industry. One provides conclusive evidence of the effect of coating steel with a thin layer of tin before it is painted. Such articles as cycle mudguards, window frames, sidecar chassis, when so treated, retain their original appearance after exposure to the weather, but when lacking the protective coating, though otherwise prepared and exposed in the same way, rust badly.

When, in 1937, Dr. D. A. Oliver of the Permanent Magnet Association, Sheffield, lectured to the Institute of Physics on permanent magnets, the best material he could describe was the British alloy Alnico, containing approximately 18 per cent. nickel, 10 per cent. aluminium, 12 per cent. cobalt, 6 per cent. copper and 54 per cent. iron. This material had a remanence (B_r) of about 7500 gauss, a coercivity (H_c) of about 500 oersted, and a value of $(BH)_{max.} = 1·6 \times 10^6$ ergs per c.c. In a paper in *British Science News* (December 1949) T. E. Kerr of the same Association gives a brief account of the latest results obtained in the Research Laboratory maintained by the Association. Until recently Alcomax II was the most satisfactory material for permanent magnets developed by the Association. For this alloy $B_r = 12,400$ gauss, $H_c = 570$ oersted and $(BH)_{max.} = 4·3 \times 10^6$ ergs per c.c. This value of the magnetic energy is adequate, but the coercive force is smaller than is desirable, in view of the demand for very short magnets in wireless and television apparatus. The coercivity can be improved without diminishing the value of $(BH)_{max.}$ by adding niobium to the alloy and two new alloys Alcomax III and Alcomax IV, containing this substance, are now available. For Alcomax III $B_r = 12,200$, $H_c = 650$ and $(BH)_{max.} = 4·75 \times 10^6$. A further improvement, due to Dr. K. Hoselitz, is obtained by growing the columnar crystals in the casting with their axes in the direction of the subsequent magnetisation. A sample of Alcomax III so prepared gave the following figures : B_r 13,500, H_c 745 and $(BH)_{max.}$ 7·05 $\times 10^6$—a notable advance on the Alnico of 1937.

The twenty-second Annual Report of the Council for Scientific and Industrial Research of the Commonwealth of Australia for the year 1948 shows that the Council is now responsible for a vast number of investigations, covering a wide field of scientific interest. The greater part of the Report (108 pages out of 141) is devoted to short summaries of this work classified under some twenty headings

from Aeronautics to "Tribophysics" (a term which here covers not only problems concerned with friction and lubrication, but also metal physics and explosives), and including such diverse matters as the banding of mutton birds (the concern of the Fisheries section), radio reflections from the moon, and the qualities of cherry yeast. The net cost of all the Council's work to the taxpayer appears to have been a little over 1·5 million pounds, a small sum when compared with the financial value of many of the results obtained.

The D.S.I.R. has issued an interesting account of the attempts made by the Pest Infestation Laboratory to devise an insect-proof material which could be wrapped round packages, and which should be cheap and easy to handle. First attempts to devise such a wrapping failed for reasons given in the report. For example, corrugated cardboard impregnated with D.D.T. failed because the smaller insects, "which love to crawl along tunnels and cracks, did not realise that, after boring through the crinkled layer, they had penetrated into a tunnel and went straight through the layer of cardboard beyond, while the bigger insects were too large to get through at all—both sizes thus failing to pick up a lethal dose of the D.D.T." Success was achieved by the use of cellulose wadding. "Several layers of this very thin material, impregnated with D.D.T., are used together, and the insect, on getting through the first, discovers a labyrinth of tunnels and folds along which it happily threads its way, instead of going straight through. In this way it picks up enough D.D.T. to kill itself." In practice the wadding would be sandwiched between two layers of ordinary papers to prevent the contamination of goods by D.D.T. and so that it could be handled easily.

Strong support for the theory of thermal conduction in solids, put forward by Debye many years ago, is provided by experiments on the transmission of ultrasonic waves through metal, quartz and glass rods, of which a simple description is given by W. P. Mason in the *Bell Laboratories Record*, December 1949. Since heat is a manifestation of the energy of vibration of crystal lattices, Debye suggested that it is transmitted from one layer of molecules to another in the same way as an acoustic wave. The difference of speed is accounted for by the difference in frequency—for heat the frequencies are mostly in the 10^6 megacycle band, while audible "sounds" are in the 1 kilocycle band. Using quartz crystals held against the two ends of a rod, one as the source of the waves and the other as receiver, it is possible to investigate the passage of

ultrasonic waves in the 10-megacycle band and, far as these are from the thermal band, they yet begin to show the characteristics of heat transmission.

When an acoustic wave passes along a rod in which the crystals are aligned in the direction of transmission, it is attenuated only by mechanical hysteresis. The loss of acoustical energy per cycle is constant, so that the total loss is proportional to the frequency. (The "lost" energy is converted into heat and so does not occur with "heat" waves.) If the crystals are oriented at random, the main wave is attenuated by reflections at the crystal boundaries. For wave-lengths greater than about three times the grain diameter this "scattering" loss is proportional to the fourth power of the frequency; for much smaller wave-lengths it is independent of the frequency, but inversely proportional to the grain diameter. The scattered energy continues to travel through the rod, but takes longer to reach the end because of the irregularity of the path it follows. These statements are confirmed by experiment. In particular, the energy of a pulse started at one end of a brass rod having an average grain diameter of 1·25 mm. was almost entirely scattered before it reached the other end. What appeared there was not a sharp pulse, but a disturbance which quickly reached a maximum and then tailed off "slowly." Since the scattering is proportional to the fourth power of the frequency, it becomes very great for waves in the thermal band ; all the thermal energy travels by reflected paths. Curves showing the variation with time of the temperature at one end of a rod due to a " heat pulse " at the other were calculated from the equations for heat transmission, and the results obtained by experiment for a sound pulse show the similarity which would be expected from the Debye theory.

ESSAY REVIEW

SIR FREDERICK GOWLAND HOPKINS. By PROFESSOR C. RIMINGTON, M.A., Ph.D., D.Sc., University College Hospital Medical School. Being a Review of **Hopkins and Biochemistry, 1861–1947.** Papers concerning Sir Frederick Gowland Hopkins, O.M., P.R.S., with a selection of his addresses and a bibliography of his publications. Edited by Dr. JOSEPH NEEDHAM, F.R.S., and Dr. ERNEST BALDWIN ; with a Foreword by Prof. A. C. CHIBNALL, F.R.S., and contributions by Dr. MALCOLM DIXON, F.R.S., Dr. LESLIE J. HARRIS and Dr. MARJORY STEPHENSON, F.R.S. A Commemoration Volume prepared on the occasion of the First International Congress of Biochemistry, Cambridge, 1949. [Pp. x + 361, with 11 plates and 1 other illustration.] (Cambridge : W. Heffer & Sons, Ltd., 1949. 18s. net.)

" A MAN who can be regarded as one of the greatest scientists and, in his own sphere, the greatest scientist of his time, is very rare. A man who is esteemed by everybody and regarded with affection by all his friends, colleagues and pupils, is by no means common. The combination of both these qualities in one person presents us with a man of such outstanding individuality that the degree of knowledge, skill, judgement and sympathy required to give his biographic lecture is almost unattainable," says Sir Edward Mellanby in his admirable memorial tribute to Sir Frederick Gowland Hopkins. It was an inspiration of the happiest kind which led the Editors of the volume under review to assemble under one cover a selection of Hopkins' most significant writings and of the appreciations of others and to complete this work in time for its distribution to those attending the First International Congress in Biochemistry in Cambridge, 1949. The Congress was, in itself, a memorial to Hopkins' life's work and here in these pages one may retrace the thoughts by which in the short space of some thirty years (1898–1929) he founded and established the subject of biochemistry in Great Britain and became deservedly acclaimed as one of its greatest living exponents. His own autobiographical fragment, the essays of his colleagues and the illuminating commentary by Dr. L. J. Harris upon Hopkins' writings and achievements add further to the charm and value of this volume.

Hopkins approached biochemistry by way of analytical chemistry

and then medicine, and his earlier studies were naturally concerned with the identification and determination of body constituents ; yet even in his earliest scientific efforts the question " How ? " was always associated with the question " What ? " In 1935, describing his boyish experiments of 57 years earlier with the bombardier beetle *Brachinus crepitans*, which, on being alarmed, ejects a violet vapour into the air, he says, " I felt an intense curiosity to know not only how this volatile stuff could be made and stored but, in particular, what the stuff could be. . . . Though the designation was not yet invented, I became there and then a biochemist at heart." Surely any boy might have wondered what the coloured vapour was, only a Hopkins was immediately curious to know *how* it was made and stored.

Passing down the years we come to his work on lactic acid production in muscle, where for really the first time he had the experience of working with living tissue, and this is how his mind reacted to that experience : " In the evolution of muscle it would appear that advantage, so to speak, has been taken of this phase in carbohydrate degradation and that, by appropriate arrangement of the cell elements, the lactic acid, before it leaves the tissue in its final combustion is assigned the particular position in which it can induce those tension changes upon which all the wonders of animal movement depend." The ideas of dynamic flux and of the integration of structural organisation with chemical change to subserve some vital function of the cell are fully and freely expressed in this passage. No matter that lactic acid plays a subsidiary rôle nowadays in the biochemistry of muscle, the intellectual achievement remains undiminished.

Before penning the Croonian Lecture in 1915, from which the above quotation is taken, Hopkins had already advanced far with this new concept of a dynamic life of the cell and had enunciated his ideas in a remarkable address to the Physiological Section of the British Association in 1913. He was still a pioneer : " I have made it my business during the last year or two to learn, by means of indirect and most diplomatic enquiries, the views held by a number of our leading organic chemists with respect to the claims of animal chemistry. I do not find any more the rather pitying patronage for an inferior discipline, and certainly not that actual antagonism, which fretted my own youth ; but I do find still very widely spread a distrust of the present methods of the Biochemist, a belief that much of the work done by him is amateurish and inexact." Reading the address against this background, one is astounded by its wealth of prophetic insight, by the masterly sweep of its intellectual progress

and by the multitude of suggestions which today are proven facts. It is in this address that the famous phrase occurs when speaking of the cell, " Its life is the expression of a particular dynamic equilibrium which obtains in a polyphasic system."

I would like to touch on another point which has been generally overlooked by those who have commented upon Hopkins' life and work. It is the credit due to him for envisaging at an early stage in the development of biochemistry the possibility and importance of chain reactions and sequences. We are today so familiar with various " cycles " that the boldness of the original conception tends to become obscured, yet in his work upon glutathione and its possible functions the idea is introduced that intermediate hydrogen transport may be accomplished in living tissues by a chain of suitable acceptors.

Although Hopkins' biochemical writings all present evidence of the profound philosophical background which he had developed for his subject, and although it is clear that he had read and pondered the writings of Whitehead and similar leaders of philosophical thought, it was rarely that he devoted an address to a philosophical theme. The one given in 1927 and reproduced in this book is a noteworthy example. Here he seems to have accepted as intolerable the challenge in J. S. Haldane's pronouncement, which he quotes, " The new physiology is biological physiology—not biophysics or biochemistry. The attempt to analyse living organisms into physical and chemical mechanism is probably the most colossal failure in the whole history of modern science." He is at infinite pains to discover just what is implied in this statement and to deal with it fairly. The attitude of the vitalist was to him always inhibitory and therefore unjustifiable and " a bias in favour of ' organicism ' may lead to misinterpretation of experimental data just as readily as the bias in favour of too facile ' mechanism ' which ruled in the later years of the last century." Without expending effort to analyse the organism into chemical mechanisms, our knowledge and grasp of it as a whole would be superficial and incomplete. He concludes : " There are aspects of the organism which must be left to the philosopher to deal with, if he can. But surely the soundest philosophy is that which, instead of ignoring any of the hard won data of experimental science, should use them all—each in its place—in an endeavour to arrive as nearly as possible at reality."

Hopkins possessed a whimsical sense of humour which added greatly to his personal charm. He was fond of repeating :

> I often wonder as I go
> What makes the little daisies grow,
> And when I die, as die I must
> And dust at length returns to dust,
> Some other fool will want to know
> What makes the little daisies grow !

One mark of his greatness, to which every word in this book bears witness, whether in appreciation by others or from his own hand, is Hopkins' deep yet noble humility of character. One cannot close better than with these lines from Goethe, a poet whom he himself not infrequently quoted :

> Was kann ein Mensch im Leben mehr gewinnen,
> Als dass sich Gott-Natur ihm offenbare ?

REVIEWS

MATHEMATICS

Introduction to Algebraic Geometry. By J. G. Semple and L. Roth.
[Pp. xvi + 446, with 16 figures.] (Oxford : at the Clarendon Press,
1949. 30s. net.)

This book provides an excellent introduction to the study of algebraic
geometry. It caters for the student who is taking up the subject in earnest
after completing the usual course in the theory of conics, quadrics, etc.

An introductory chapter lays down general concepts and primary proper-
ties of collineations, algebraic manifolds and correspondences in projective
linear space over the complex field.

Chapters II–V deal mainly with plane curves. Their structure is described
in the elementary aspects, with special reference to the rational and elliptic
types. By means of a finite number of quadratic transformations, it is shown
how to transform a curve into one with only ordinary singularities. Then we
have correspondences on a line and in a plane, Bezout's theorem, Plücker's
equations, invariance of genus, and a discussion of curves in space. The
simplest case of Noether's $Af + B\phi$ theorem follows, with associated topics.

Chapters VI–VIII are about linear systems of curves in a plane and of
surfaces in space, and the projective models of such systems. Many famous
surfaces and threefolds are introduced in this way, besides the theory of
Cremona transformations and involutions.

Chapter IX is an account of the projective characters of curves and
surfaces in S_r, with particular references to the case $r = 3$.

Chapter X is on the geometry of systems of lines in S_3 and S_4, and on the
representation of lines in a system by points of an algebraic manifold.

Chapter XI introduces Schubert's calculus and is principally concerned
with enumerative problems for lines and for quadric surfaces ; it concludes
with a discussion of the validity of the specialisation principle.

Chapters XII and XIII open up further ground by their accounts of the
invariantive theory of curves and surfaces. The canonical series on a curve,
canonical system of curves on a surface, and the Riemann-Roch theorem for a
curve are among the fundamental topics discussed ; finally there is an outline
of further developments.

The exposition is clear and reflects the enthusiasm which the authors feel
for their subject. Prof. Semple and Mr. Roth have themselves made notable
contributions to the theory ; it is therefore gratifying to find that some of
their work is presented in this book in a form easily grasped by beginners.

A feature of particular value is the emphasis on the technique of representa-
tions. Thus the structure of a linear system is clarified by consideration of
its projective model, and vice versa ; and the geometry of line-systems is
similarly illuminated by the study of Grassmann manifolds : the student

learns to think of an r-dimensional space with the same ease as one of 2 or 3 dimensions.

The presentation of the subject of algebraic geometry is from the point of view of the Italian School, the appreciation of which was so effectively taught by Prof. H. F. Baker. " Modern algebra " is now playing an increasing part in geometry, affecting both the centres of interest and the language of the subject. It is therefore interesting to speculate on what adjustments will be effected between the two points of view, especially at the level of this book.

The book is clearly set out in the best Oxford style. A valuable feature is the large collection of exercises, some worked in outline, some indicating further ideas, and all stimulating. Each chapter ends with a list of books for subsequent reading. The very full list of contents seems intended to make an index unnecessary : but nevertheless an index would still have been useful.

The authors must have found it anything but easy to decide how much ground to cover and how deeply to penetrate into it. One infers that they have been guided by the *introductory* purpose of their writing. Consequently, certain aspects of theory are presented in their simplest forms, the difficulties of the general cases being indicated but left to be read elsewhere. As a result, nothing is very difficult, which may be a good thing : but one could have wished that the ultimate dependence on other textbooks had been lessened.

In conclusion, the reviewer wishes to express the personal enjoyment he has in reading the book, and to commend it warmly.

<div style="text-align: right">J. W. A.</div>

Five-Figure Tables of Mathematical Functions. By JOHN BORTH-WICK DALE, M.A. Second edition. [Pp. viii + 121.] (London : Edward Arnold & Co., 1949. 6s. net.)

THE first edition of this well-known collection of five-figure tables of mathematical functions was first published in 1903 and has been frequently reprinted since. It contained among others tables of squares, square roots, powers, of natural and logarithmic trigonometric function, both circular (at sexagesimal argument) and hyperbolic, and some small tables concerning certain higher mathematical functions such as the Elliptic Functions, E and F, the Bessel Function J_n and L_n, the Γ-function and the Error integral, all supported by auxiliary tables of constants and of interpolation coefficients.

In the present second edition five-figure tables of $\log_{10} x$ for $x = 1 \cdot 000$ $(0 \cdot 001)$ $2 \cdot 999$ and of $\log_{10} \sinh x$, $\log_{10} \cosh x$ and $\log_{10} \tanh x$ for $x = 0 \cdot 00$ $(0 \cdot 01)$ $2 \cdot 00$ $(0 \cdot 1)$ $6 \cdot 0$ have been added.

Whilst there is no doubt about the popularity of these tables in the past, the original arrangement has been, in the main, retained and the table does not, therefore, incorporate modern improvements in methods of interpolation, pagination and tabular typography.

<div style="text-align: right">H. O. HARTLEY.</div>

Living Mathematics. By N. S. UNDERWOOD and F. W. SPARKS. Second edition. [Pp. x + 374, with 88 figures.] (New York, Toronto, London : McGraw-Hill Book Co. Inc., 1949. 36s. net.).

THE existence of " puzzle corners " in popular papers and magazines is evidence enough that there are plenty of amateur mathematicians who enjoy dabbling with " teasers," and many of these must at times have wished that they knew a little more mathematics. Such persons may well find this second and revised edition of *Living Mathematics* both instructive and entertaining.

The book is in two distinct parts, called respectively " Algebra " and " A look over the field."

The first gives a detailed account of elementary algebraic processes, introducing linear and quadratic equations, functions and graphs, logarithms and series (with applications to Compound Interest and Annuities). There are numerous examples for the reader to work out, both easy and harder, and answers are supplied.

The second part of the book deals with elementary analytical geometry, calculus, trigonometry, probability (with its application to Insurance) ; and a brief survey of theory of numbers. This second part is nothing like as detailed as the first, and he would be a fairly able amateur who, with no previous knowledge of the subject, managed to make much of, for example, the calculus section. But the authors claim only to be taking " a look," and they would surely be satisfied if they whetted the appetite of the reader sufficiently to drive him to seek more detailed information from orthodox textbooks.

The book is written in a breezy, humorous style, and many teachers would learn something from its vividness of expression. Annuity and Discount Tables are supplied, as well as those concerned with Logarithms and Trigonometry. The book, which is beautifully bound and printed, could take its place on the shelf next to *Mathematics for the Million*.

RAYMOND WALKER.

ASTRONOMY AND METEOROLOGY.

The Structure of the Universe. By G. J. WHITROW, M.A., D.Phil., F.R.A.S. Hutchinson's University Library, No. 29. [Pp. 171.] (London : Hutchinson's Scientific and Technical Publications, 1949. 7s. 6d. net.)

THE aim of the series is to provide " popular yet scholarly introductions for the benefit of the general reader, but more especially for the unprofessional student who wishes to pursue his chosen subject systematically up to something like a University standard." While a university standard of cosmology may be an ill-defined concept, it is difficult to believe that a text which contains less than a score of equations could fulfil this aim. But in attempting the impossible it is not surprising that the author falls short of the ideal—in fact, it is surprising that he has succeeded in conveying so much difficult matter in a lucid manner.

The treatment develops three interdependent themes. Modern observation of the extragalactic nebulæ is approached by an historical survey, where the difficulty of interpreting " crude " observational data is emphasised. General relativity and its associated cosmologies lead to the second theme, the theoretical foundations of science. In the conflict between the Baconian and Kantian approaches to natural philosophy, the reader is not long left in doubt as to the opinions of the author as a member of the Oxford school of Kinematic Relativists. This philosophical discussion is a necessary prelude to the third topic, the Eddington and Milne theories of the constants of nature. The treatment of these *a priori* epistemological approaches to cosmology is the most important, if the most exacting, task of the author, and it is a pity that an impartial critical faculty so evident throughout most of the text should at this point be partially eclipsed by personal enthusiasm.

A gallant attempt has boon made to satisfy both the layman and the serious student. If the former finds much that is incomprehensible, and the latter only enough to whet his appetite, this is due to the inherent difficulties of the subject, and not to any shortcomings of authorship. Broad in outlook, and up-to-date in technical content, it can be recommended as a useful elementary introduction to one of the most fascinating realms of scientific speculation.

M. W. O.

Some Recent Researches in Solar Physics. By F. HOYLE, M.A. Cambridge Monographs on Physics. [Pp. xii + 134, with 8 figures.] (Cambridge : at the University Press, 1949. 12s. 6d. net.)

AN up-to-date treatment of solar physics is an urgent need at the present time, for developments in this field in the past decade have rendered existing texts hopelessly inadequate. Pleasure is thus the first reaction to the appearance of a monograph which aims " to provide a concise account of the present state of solar physics," especially one by an author who has brought an original mind to refresh so many fields of theoretical astrophysics. The greater, therefore, is the disappointment on finding that in fact it provides nothing of the kind.

A summary of the contents suffices to show that the claim cannot be justified. The first chapter takes the briefest of glances at sunspots and the sunspot cycle, and solar rotation, including a theoretical discussion of the growth and decay of sunspot magnetic fields. In the second chapter, observational data on the chromosphere and corona are given : transient chromospheric phenomena (flares, prominences, etc.) are dealt with adequately ; but far too little space is given to observations, with and without an eclipse, of normal conditions. In this chapter is also included a thumb-nail sketch of the ionisation equilibrium and emission of radiation in those regions. The next two chapters (which together comprise more than a third of the text) are devoted to a detailed development of the author's theory of the dependence of the chromosphere and corona upon accretion of interstellar matter. The last three short chapters deal with electromagnetism in solar physics, solar and terrestrial relationships, and radio emission from the sun. The Fraunhofer lines and their formation receive scant attention. The main text was written in 1947. Rather than embark upon a complete revision, the author has included an appendix dealing with recent theoretical and experimental work, primarily in the field of solar-terrestrial relationships. (It is unfortunate that no mention is made of the long-wave radio phase anomalies, which are of paramount importance to the solar physicist because of their very close correlation with solar flares.)

The new series of monographs, of which this is one of the first members, has developed out of the earlier Cambridge Physical Tracts, but, whereas the purpose of the Tracts was largely the presentation by the authors of their own work, the emphasis of the new series is stated to be on more general treatment. Mr. Hoyle's text is in the spirit of the Tracts, and not of the new series, and it is difficult to escape the conclusion that it was written as such. Pruned of its pretension to completeness, it becomes a useful account of the accretion theory of chromosphere and corona. While the specialist reader to whom it should really appeal will find little that could not be read in a few original papers, it is pleasing to find developed as a coherent whole in its observational perspec-

tive a theory which, if not generally accepted, is nevertheless original and stimulating.

Among the pages is much useful information, both of experimental results in tabular form, and theoretical treatments of interesting problems. It leaves the gap in solar physics literature as wide as ever, but it does neatly fill a niche of its own.

M. W. O.

Atmospheric Turbulence. By O. G. Sutton. Methuen's Monographs on Physical Subjects. [Pp. viii + 107, with 4 figures.] (London: Methuen & Co., Ltd., 1949. 6s. net.)

The word *turbulence* is commonly taken to connote an apparently irregular type of fluid flow so small in scale that its details are effectively beyond the wit of man to describe. Like Clerk Maxwell with molecules, the physicist regards the problem of turbulence as one to be solved by a statistical treatment, the physical consequences of a given field of turbulent flow, such as the transfer of heat, matter and momentum, being represented by expressions involving mean products of eddy velocities and the like. These expressions are then to be related to the properties of the mean motion and the conditions at the boundaries. There is, however, no necessity to consider turbulence as restricted to small-scale motions. It is more fruitful perhaps to regard it as a technique to be applied to any system possessed of a number of modes of motion. Then, in the study of any particular mode, the effects of smaller-scale modes are to be allowed for by certain of their statistical properties. The laws of turbulence will evidently depend on the physical nature of those smaller-scale flow patterns and can be expected in general to depend on scale. This approach would appear to be eminently suitable in meteorology since the atmosphere undoubtedly possesses many modes of motion of scale varying from the microscopic to the global.

Little, however, of this attitude is to be found in Prof. Sutton's monograph, which is concerned almost exclusively with what may be called inner boundary-layer turbulence, and this he deals with in mathematical detail. The choice is understandable, for not only is he a leader in this particular branch but it has made more progress, albeit of a rather superficial kind, than the study of atmospheric turbulence generally.

Having introduced the reader to the salient features of turbulent flow on the laboratory scale and in the bottom 100 metres or so of the atmosphere, he proceeds to an examination of the mathematical treatments which have been adopted in the study of the latter region. Empirical K (eddy viscosity) theory is quickly dismissed and we are then shown the products of Prandtl's mixing-length theory and of Sutton's formulation of the Taylor correlation-function, that function which expresses the rate at which an eddying mass of air loses its identity in motion through its environment. Formulæ are derived for the turbulent transfer of heat, matter and momentum, and for the concentrations of diffusible entities from point, line and area sources which, by adjustment of constants, can be brought into good agreement with observation. The success is apparently considerable but it is attained without, at any stage, more than the slightest possible physical basis—much could be derived from simple dimensional analysis, a notable exception being Taylor's diffusion theorem. This is no criticism of Prof. Sutton's matter ; it represents the present state of the subject. But the reviewer feels that the severe limitations of the

treatment should have been clearly exposed ; they are not. The writer indicates that latterly a more fundamental approach has been developed but that the new methods, applied at present to motions in the laboratory, are not yet able to face the atmosphere with its complicating density gradients and multiplicity of motions.

Prof. Sutton writes very clearly and acceptably, and the book is well printed and indexed. When a second edition is called for, may one hope for some attention to be given to the boundary-layer turbulence over the sea ? The sea underlies four-fifths of the earth's atmosphere and it undoubtedly possesses qualities of specific interest.

P. A. S.

PHYSICS

A Textbook on Heat. By J. H. AWBERY, M.A., B.Sc., F.Inst.P. [Pp. x + 302, with 50 figures.] (London, New York, Toronto : Longmans, Green & Co., 1949. 15s. net.)

In recent years the subject of Heat has tended to become the Cinderella in physics courses. A large number of causes has contributed to this failing interest. The spectacular discoveries and rapid advances in other fields attract such attention that in planning any course of a comprehensive character the time allotted to the well-established branches is liable to be severely restricted. The author of this book in a forceful preface condemns this by implication and claims for Heat a position as one of the three main branches of physics, the others being mechanics and electromagnetic theory, a study of which is basic to all true study of physics.

It is not surprising then that the form and content of this book differ from other texts. Much traditional material has been omitted and an attempt made to introduce the wide range of topics embraced by the subject. Thus conduction and convection of heat are treated more adequately than is usual in books intended for a comparable class of readers. A chapter of over twenty pages is devoted to statistical mechanics. It is obvious that the more recondite topics dealing with fundamentals cannot be discussed in a chapter of this length but the mathematics involved in the simpler deductions of the distribution laws is straightforward, and the subject may with advantage be introduced to students at an earlier stage than is customary.

Although a summary of much experimental work is given, as is to be expected from an experimentalist of Mr. Awbery's standing, it is disappointing to find no really detailed descriptions. Great accuracy is obtainable in thermal measurements, but only by meticulous attention to details, and a general description omits just these essentials. A detailed description of at least one typical experiment in each section would add considerably to the value of the book.

The standard is uneven, but in spite of this the author has produced a useful volume which will be welcomed by many degree students.

F. E. H.

An Introduction to Molecular Spectra. By R. C. JOHNSON, M.A., D.Sc. [Pp. xiv + 296, with 8 plates and 151 figures.]ʼ (London : Methuen & Co., Ltd., 1949. 40s. net.)

PROBABLY the best-known and most useful English introduction to Atomic Spectra is Dr. Johnson's excellent monograph (1946) in Methuen's series on

Physical Subjects. It seems safe to predict that the larger work now under review will quickly establish for itself a similar place in the literature of the more complex subject of Molecular Spectra. Books in our language on this subject are still comparatively few. The Physical Society published the present reviewer's *Report on Band Spectra of Diatomic Molecules* in 1932, when the subject was in a state of rapid development both on the theoretical side and in the laboratory. The only comprehensive work to appear in English since then is the translation of G. Herzberg's *Molekülspektren und Molekülstruktur*, in two fair-sized volumes : 1 on *Diatomic Molecules* (1939), and II on *Infra-red and Raman Spectra of Polyatomic Molecules* (1945) ; the promised volume III on *Electronic Spectra of Polyatomic Molecules* has not yet appeared. All other books published in recent years deal only with certain aspects of the subject and its applications ; and this fact makes the appearance of Dr. Johnson's comprehensive work all the more welcome.

The author is well known to spectroscopists for a notable series of experimental investigations of diatomic spectra, carried out by himself and his pupils at Queen's University, Belfast, and King's College, London, before his appointment as Master of Queen's College in the University of Melbourne.

Within the limits of an ordinary mathematical knowledge, the book provides honours graduates in physics or chemistry with a sound basis for further study and practical work. Results of Wave-Mechanics are introduced wherever necessary, but familiarity with the use of the method is not assumed ; and the treatment of electronic structures of polyatomic molecules excludes matters involving a knowledge of Group Theory. A prior knowledge of the principles of atomic spectra is, of course, essential, and is assumed ; the author's monograph, mentioned above, provides all that is necessary.

A systematic treatment of the band spectra and structures of diatomic molecules occupies the first twelve of the fifteen chapters. Then follows one chapter, by far the longest in the book, on polyatomic molecules and their spectra. The remaining two chapters deal with Raman spectra and with various important applications of molecular spectroscopy in astrophysics, chemistry and biochemistry. Numerous tables and line diagrams illustrate the text, and a number of well-chosen spectrograms are excellently reproduced in the Plates.

We are indebted to Dr. Johnson for a most valuable textbook, in which the choice and ordering of the material, the thoroughness and clarity of the treatment, and the printing and production are all admirable. In due course the demand for a second edition will, no doubt, provide an early opportunity for the correction of the few errors that have been detected—they appear to be remarkably few in consideration of the intricacy of the subject and its notation ; mention of one error may be helpful to readers : on p. 296 " Zeeman " is indexed as " Woeman."

<div align="right">W. J.</div>

Viscometry. By A. C. MERRINGTON, B.Sc., Ph.D., F.Inst.P. [Pp. viii + 142, with 60 figures.] (London : Edward Arnold & Co., 1949. 16s. net.)

SINCE the publication in 1931 of Dr. Barr's Monograph on Viscosity, the only book devoted entirely to the subject, many important developments have been made in the methods of measuring viscosity. The volume under review fills the need often felt by research workers for a book which gives an up-to-date account of this important subject.

After an interesting historical introduction in Chapter I, the author proceeds in Chapters II, III and IV respectively to deal with capillary viscometers, rotational and oscillational viscometers, and the method of the falling sphere. These chapters give a lucid and systematic account of most, if not all, the theoretical and practical developments in viscometry which have improved the accuracy of the techniques employed as well as widening their field of application.

Chapter V is devoted to technical viscometers. The principal types used in the oil industry in various countries are described in some detail, with the latest specifications, together with conversion formulæ as suggested by different investigators, conversion tables being supplied in the appendix. An interesting account of a number of viscometers used in other industries is also included.

Chapter VI gives a condensed treatment of methods for determining the viscosity of gases ; whilst Chapter VII covers the miscellaneous methods of viscometry falling outside the categories already referred to in the preceding chapters. Some of the methods described in Chapter VII will be found suitable for investigations on the variation of viscosity with various applied conditions, and others will be adaptable to the peculiar needs of certain industries.

Chapter VIII is concerned with methods for very viscous materials.

The book concludes in Chapter IX with an account of the applications to non-Newtonian flow. This phenomenon is treated briefly, and then comes an interesting discussion of the various methods for measuring anomalous viscosity, attention being drawn to the special difficulties of the problem and how they are surmounted.

The author's treatment is concise but adequate, in most cases, to provide a working knowledge of the subject. The explanations are clear, and the field covered is extensive. A comprehensive search has been made into the literature of the subject, and the very generous bibliographies at the end of each chapter would meet the requirements of the reader seeking further details of the subject matter discussed. Altogether the volume can be recommended as extremely useful to those concerned with the science of viscometry.

<div style="text-align: right">HU PAK MI.</div>

High-Polymer Physics. A Symposium, edited by HOWARD A. ROBINSON. [Pp. xiv + 572, with numerous figures.] (Brooklyn : Remsen Press Division, Chemical Publishing Co., Inc., 1948. 90s. net.)

HIGH-POLYMERS are compounds consisting of giant molecules which are made up by linking together a great number of identical basic units. In most cases these molecules have the form of long chains which may be linked up with each other by cross-links, thus forming compact networks. Owing to this structure the physical properties of high-polymer substances are in many ways considerably different from those of " ordinary " substances composed of small molecules. The " properties of matter " as one finds them treated in the current textbooks on physics are those of substances of the latter type, because physicists in the past have mainly studied the physical behaviour of bodies with comparatively simple molecular structures. However, a large number of " natural " substances like organic fibres and resins, rubber, cork, etc., which are widely used, are now known to be high-polymers, and in recent years the chemists have produced a great variety of " artificial " high-polymers, like artificial textile fibres, synthetic rubber and resins, various glasses and

so-called " plastics," etc., which are used for industrial purposes on an ever-increasing scale. Thus physicists have started to study the physical properties of high-polymers systematically, and this has already led to the establishment of a new branch of physics which is not only most interesting in itself but also promises to be of considerable importance for industry.

The present book is a report on a symposium on High-Polymer Physics, held under the auspices of the American Physical Society in New York in 1946. It contains 23 papers by 39 physicists and chemists working in this field. Some of the papers describe new methods for the investigation of the molecular structure of high-polymers and for determining their molecular weight by physical methods, such as the measurement of viscosity and diffusion, absorption of infra-red light, scattering of X-rays and visible light. Others are devoted to the systematic study of the mechanical properties of such substances as textiles, rubber, cork, etc., in which elastic and plastic features are combined, the thermodynamics of these systems, their thermal expansion, the influence of temperature on their mechanical properties, and explanations of these phenomena on the basis of their molecular structure. Another group of papers deals with the chemical physics of solutions of high-polymers and their dynamic properties, for example diffusion, thermal diffusion, viscosity and sedimentation and the behaviour of high-polymer gels. Finally, apparatus, specially designed for measurements of the kind, are described in detail.

Naturally in a collection of papers of this sort the contributions are not all of a uniformly high standard. It is also to be regretted that the various authors use different notations for the same quantities, and that there are no cross-references between papers dealing with the same subject. However, the study of this book makes fascinating reading, and it will doubtless be of great value as a source of reference to workers in its field.

<div align="right">R. Fürth.</div>

Ions, Electrons, and Ionizing Radiations. By James Arnold Crowther, Sc.D., F.Inst.P. Eighth edition. [Pp. x + 322, with 123 figures, including 7 plates.] (London : Edward Arnold & Co., 1949. 21s. net.)

That a book on this rapidly changing subject should have reached the eighth edition thirty years after first publication is a tribute to author and publisher. Surely the great majority of physicists now active have used the book as students or teachers (or both), and will know that it gives a sound, unpretentious but very readable introduction to what is sometimes called " atomic physics." With the new revisions and additions the eighth edition can be recommended to a new generation of students as a good first text on the subject. The changes include a new chapter on Nuclear Energy and substantial revisions of several others. Just a few things have escaped Prof. Crowther's vigilant eye. Some of his values for the fundamental constants differ slightly from those recently collected by R. T. Birge (*Phys. Soc. Rep. Progr. Phys.*, 7, 90, 1942). Some of the experimental methods and results described in Chapter VIII (Emission of Electricity by Hot Bodies) are out of date and might well be revised, and to a less extent the same remarks apply to Chapter IX on photoelectricity. The " mesotron " has now been re-christened " meson." These are, however, minor criticisms, and we hope that Prof. Crowther is now preparing a ninth edition, and will add titles of recent books and review papers to the helpful lists at the ends of the chapters. It

might also be possible to find space for a note on the exciting developments in the use of photographic plate methods of studying nuclear disintegrations.

F. A. V.

Introduction to Atomic Physics. By S. TOLANSKY, Ph.D., D.I.C., D.Sc. Third edition. [Pp. xii + 371, with 5 plates and 115 figures.] (London, New York, Toronto : Longmans, Green & Co., 1949. 15s. net.)

THIS third edition has been brought up to date by adding new chapters on nuclear physics and by revising the chapter on cosmic rays. As in previous editions, the book opens with an account of electricity in gases, cathode rays, positive rays and the mass spectrograph. Following this, chapters are devoted to Quantum Theory, Thermionic Emission, Photoelectricity, Atomic Spectra, X-rays, Crystals, Wave Mechanics and Electron Collisions in Gases. The last 150 pages of the book are devoted to Radioactivity, Nuclear Physics and Cosmic Rays, with a final chapter on Relativity. Some of the errors of the previous editions have not been corrected : for example, the diagram of a cascade shower on p. 296 is still misleading as it suggests the *absorption* of an electron by a nucleus when radiation is produced instead of a " bremsstrahlung " effect.

W. E. DUNCANSON.

The Theory of Atomic Collisions. By N. F. MOTT and H. S. W. MASSEY. Second edition. International Series of Monographs on Physics. [Pp. xvi + 388, with 69 figures.] (Oxford : at the Clarendon Press, 1949. 35s. net.)

THE pattern of this second edition follows closely that of the first, containing chapters on scattering by various types of central forces ; relativistic wave equations and electron spin ; discussion of the Born approximation and other relevant approximate methods ; a very useful treatment of the general theory of atomic collisions ending with a summary of the available methods and their limit of applicability ; elastic scattering of both fast and slow electrons ; inelastic collisions ; collisions between massive particles ; and relativistic two body problems. The majority of these chapters have been altered to bring the book abreast with the more recent developments. On the whole, the basic methods are still the same, but the chapter on nuclear collisions has been rewritten to bring it up to date with the large amount of recent work on the subject. A very useful account is given of the application of the method of the collision complex to nuclear collisions. Although one cannot expect in such a book an exhaustive account of this subject, a new chapter is added which gives, in concise form, the results of much of the recent work, both theoretical and experimental, ranging from the scattering of nucleons by nucleons to the magnetic scattering of slow neutrons. This edition, in content and production, maintains the high standard of the first edition.

W. E. DUNCANSON.

Excited States of Nuclei. By S. DEVONS, Ph.D.' Cambridge Monographs on Physics. [Pp. x + 152, with 27 figures.] (Cambridge : at the University Press, 1949. 12s. 6d. net.)

THE Cambridge Monographs on Physics, of which this is one of the first titles, are intended to carry on, broadly, the aims of the pre-war Cambridge Physical

Tracts. The present-day difficulties of production are recognised in so far as the intention of frequent revision, which was planned to be a feature of the tracts, is abandoned, and the individual volumes of the present series are accordingly to be rather more comprehensive in scope.

In *Excited States of Nuclei*, Prof. Devons has set a brilliant standard which the series will indeed do well to maintain. To the specialist in this field the book is clearly indispensable, but it will also appeal strongly to the much larger body of physicists, with a broad knowledge of the experimental data on nuclear disintegration, of the main theoretical approaches to a nuclear model and of the usual quantum mechanical forms of interaction cross-sections, who have not been under the necessity of orientating their knowledge towards this topic. For these, the essentially "horizontal" organisation of a Monograph offers a most stimulating and fruitful viewpoint.

After a short introductory chapter, the scope of accessible material is treated phenomologically in three chapters on "Excitation of Bound States," which includes a most interesting section on β-decay, "Excitation of Virtual States," including a brief comparative survey of slow neutron techniques, and "Radiative Transitions." In a final chapter the main theoretical approaches are surveyed. All of these chapters are characterised by a clarity of expression which has made possible that extreme condensation of material which is essential when so large a subject is treated in a volume of this size. There is room for regret, however, that space has not been found at the beginning of the final chapter for a brief survey of the ground covered by present experimental results. Prof. Devons considers the obvious drawbacks of attempting such a survey to outweigh its possible advantages, but it is precisely the less-specialised reader who feels the need for a résumé of the scope and nature of the data given in the earlier chapters, and against a survey of this kind the arguments do not seem compelling.

<div align="right">J. G. WILSON.</div>

Radioactive Measurements with Nuclear Emulsions. By HERMAN YAGODA. [Pp. ix + 356, with 75 figures.] (New York : John Wiley & Sons Inc. ; London : Chapman & Hall, Ltd., 1949. 40s. net.)

PHOTOGRAPHIC plates for recording tracks of nuclear particles have been evolved recently as a tool for their detection equal in importance to cloud chambers and electronic counters. The applications of these plates in nuclear and cosmic ray physics are now widely known, but their potentialities in other fields have not been fully realised. Yagoda's book provides the fundamental knowledge required for the use of such photographic materials in recording the distribution of radioactive substances in rocks and minerals and of tracers in metals and biological specimens. These records may be of two types. In one a photograph of the specimen is produced which reveals the location of the sources of radioactivity. In the other the particles emitted by the radioactive material produce recognisable tracks in the photographic layer. The first may be called an autoradiograph and the latter a track radiograph.

Detailed techniques of applications of autoradiography are described in the field of metallurgy, petrography, mineralogy, radiochemistry and biology. Although the manipulations required for each problem differ considerably the author provides the reader with the basic knowledge required, dealing with the preparation of specimens, the different response of photographic emulsions to alpha particles, electrons, protons, gamma rays, etc., the possible artifacts,

the problem of resolution and other topics. Some of the information presented on photographic materials, although it may be applicable for those used by the author, may not necessarily apply to other types.

The chapter on nuclear and cosmic ray physics is not written for the expert and could be dispensed with in its present form. The worker interested in autoradiography might find it more useful if increased emphasis were given to the potentialities of the new track recording materials as such, rather than to be made familiar with results achieved in nuclear and cosmic ray physics. The book does not contain a great deal of information on biological applications and it is to be hoped this field of intensive research will be described in much greater detail in a new edition. The book is already partly out of date, through no fault of the author, since the very recent developments in the recording of high-energy electrons will provide an entirely new field for future applications of the method. To improve the book for reference it is suggested that in the next edition the contents be arranged more logically and that the index be improved. More details in the " contents list " would also be an advantage.

The comprehensive bibliography in the Appendix is very valuable to all workers in the field of autoradiography, to whom the book in its well-presented form is warmly recommended, in spite of the blemishes mentioned above.

R. H. HERZ.

Handbook of Industrial Radiology. By Members of the Industrial Radiology Group of the Institute of Physics. Edited by J. A. CROWTHER, M.A., Sc.D., F.Inst.P. Second edition. [Pp. viii + 218, with 109 figures.] (London : Edward Arnold & Co., 1949. 21s. net.)

IT is rare to find a really successful book produced by a committee ; the maintenance of uniform standards, the avoidance of overlapping and of gaps, and the production of continuity are problems that even the most able editor must find difficult to solve. Judged against this background, the present volume must be considered a particularly successful example of co-operation. The various chapters link well together and, although some are more lucid and readable than others, each is obviously the work of an expert in his field. The only jarring note is the frequent use of unnecessary jargon, exemplified by the words " diaphragmed " and " packaged " ; however convenient such words may be in practice, they should not be allowed to appear in print.

The chapters follow a logical sequence : physical principles, X-ray equipment and accessories, photographic materials, X-radiography of heavy and light metals, gamma radiography, some unclassifiable applications—an entertaining chapter, this—and X-ray protection. These chapters cover the ground very well and it is difficult to detect any important omissions. The sections on physical principles, photographic materials, and X-ray protection may well be read by those whose interests lie in other fields of the use of X-rays.

In short, this work is one that no radiographer should neglect. To the beginner, especially, its store of accumulated knowledge and experience should prove invaluable. The Institute of Physics can be congratulated on the part it has played in causing the work to be produced.

H. L.

A Second Course of Electricity. By A. E. E. McKENZIE, M.A. [Pp. viii + 357, with 327 figures and 14 portraits.] (Cambridge: at the University Press, 1949. 12s. 6d.)

THIS is a well-written book in which the author sets out to provide a substantial basis for the work done at the Higher School Certificate and Scholarship levels in schools. In sequence it follows that of other books of a similar standard and gives a wide scope of subject matter, attractively presented, with here and there short biographies and portraits of scientific worthies. Units and quantities are systematically defined, and throughout the symbols used are those recommended by the Committee for Co-ordination and Guidance in Physics Teaching (although *i* is used for current in amperes).

Adequate mathematical treatment is given, although the author has sought to provide wherever possible a simpler presentation, aimed at circumventing the more rigorous mathematical detail and relying rather on the fundamental physical concepts. Thus Gauss's theorem is not mentioned in electrostatics, although much of the work here normally dealt with by this means is otherwise adequately presented. The Cavendish-Maxwell proof of the inverse square law, however, might well have been more fully argued, and some account of the theory of the quadrant electrometer could have been included in the text.

The work in Magnetism is competently set out, and the material in the Electricity section has been most carefully prepared and ordered. An introductory account of the M.K.S. system of units is included, and, in addition to a chapter on Alternating Current, there are several chapters dealing with modern developments and aspects of Physics—all done in a most admirable manner.

There are a number of worked examples provided in the text, together with collections of examination questions at the end of each chapter. If the book has a fault it is that experimental detail is throughout somewhat sparse, but there is much here of value, and Physics masters and students alike will find this a most helpful publication.

F. TYLER.

The Fundamentals of Electromagnetism. By E. G. CULLWICK. Second edition. [Pp. xxxi + 327, with 139 figures.] (Cambridge: at the University Press, 1949. 18s. net.)

PROF. CULLWICK's book has five main theses : (1) to abolish the use of the concept of magnetic pole as a basis of theoretical treatment ; (2) to stress the physical unreality of electric and magnetic fields ; (3) to discuss two distinct methods of calculating e.m.f. due to electromagnetic induction ; (4) to advocate the use of vector potential in treating wave theory, and (5) to recommend the adoption of the metre-kilogram-second (M.K.S.) system of units, including Giorgi's value 10^{-7} for the permeability (μ_0) of free space.

It is clear that their acceptance would involve radical changes in the teaching of the subject of electricity and magnetism, and the formulation of definitions and quantitative relationships. The reader will perhaps be surprised to learn that the author retains the conception of lines of force, and the usual quantities electric field-strength ($\mathcal{E}$), electric displacement (D), magnetic flux-density (B) and magnetic field-strength (H). The treatment of electric field is orthodox, since the physical reality of electric charge is accepted as firmly established. But in view of the rejection of magnetic pole, as being

fictitious, how are B and H defined ?   Magnetic flux is introduced (but without definition) on p. 73, then on p. 77 appears a preliminary statement that magnetic flux is " a distributed vector quantity such that when the magnitude of this quantity linking a closed path is changed, an e.m.f. (and consequently electric field) appears round that path," amplified on p. 88 into a definition of unit flux as " that flux which, linking a circuit of one turn, induces unit e.m.f. when it collapses to zero at a uniform rate in unit time."   Much later (on p. 161) follows the definition of magnetic field-strength, H, as " the gradient of magneto-motive force (m.m.f.)."   To the present reviewer these definitions seem far from an improvement on those usually used, depending on the adoption of unit magnetic pole.   But opinions differ, and the reader will, we hope, obtain a copy and form his own conclusions.   The proper sequel to a book like this of Prof. Cullwick's, and the test of its value, would be the appearance of an *elementary* textbook implementing these or similar proposals.

Mention should be made of some intriguing examples (pp. 109 *seq.*) of induced e.m.f. without change of flux linkage, or without flux-cutting ; and of the author's preference (in the last chapter, V) for the use of vector potential when dealing with the subject of electric waves, thereby eliminating magnetic field from calculations.

<div align="right">D. O.</div>

Radio-Frequency Heating. By L. HARTSHORN, D.Sc., A.M.I.E.E., A.R.C.S, D.I.C. [Pp. 237, with 102 figures.] (London :   George Allen & Unwin, Ltd., 1949. 21s. net.)

THIS book deals with both induction and dielectric heating in a straight-forward way which will interest those who have occasion to apply these comparatively new methods to particular industrial processes.

In describing generators the author confines his attention almost entirely to valve oscillators.   Some simple circuits are described and the fundamental voltage and power relations are given.   Many points of practical importance such as the protection of circuit components, the protection of operators from shocks and h.f. burns, and the use of screens and filters to reduce radio interference are mentioned.   More attention could have been given to motor alternators and spark gap oscillators, which operate at frequencies which the author has included in the radio frequency heating range, and which are used for some of the applications described in the book.   The section dealing with output circuits could also have been expanded to include details of load " matching," which are of more importance to the user than a knowledge of the causes and methods of suppressing parasitic oscillations.

The approximate theoretical power relations which apply in induction heating are derived simply and the design of coils and concentrators is described.   Some of the information given in Table II, however, is outside the range of practical usefulness.

Many practical applications of induction heating, including melting, annealing, soldering and brazing and surface hardening are described.   The author has tended to underestimate some of the practical problems, *e.g.* in describing quenching.

The theory of dielectric heating is given and the mechanism of the process is explained.   A separate chapter deals with several industrial applications, and some of the practical difficulties, such as those due to standing waves, are explained and solutions given.

<div align="right">▲ ▲</div>

A final chapter gives the approximate cost of generators and an account of the history of the subject.

Much useful information on the electrical properties of dielectric materials is tabulated, the bibliography is extensive and there are many illustrations. Some of the figures, however, illustrate principles rather than modern practice.

R. S.

Industrial High Frequency Electric Power. By E. MAY, B.Sc., A.C.G.I., M.I.E.E. [Pp. xii + 355, with 208 figures.] (London : Chapman & Hall, Ltd., 1949. 32s. net.)

IT is difficult to decide for what readers this book is intended. That so much space is devoted to the elementary theory of a.c. circuit analysis and of the triode valve suggests that the book is an introduction to the subject for the beginner. The chapters on Arc Oscillators, H.F. Alternators, and Valve Oscillators, on the other hand, are so stocked with formulæ and charts that the beginner might readily assume they were intended for the equipment designer. In spite of this appearance, the chapters seldom provide enough information for more than very rough and uncritical design ; the designer would undoubtedly look elsewhere for guidance. The chapters on Induction and Dielectric Heating provide a fairly wide survey of the industrial uses of high frequency power, though they are spoiled by the inclusion of misplaced design information. A chapter on Applications and Operating Problems includes a very miscellaneous collection of matters that have somehow failed to find a place in the previous chapters. Among them are lists of installation and maintenance advice that would be provided in much more useful form by the equipment manufacturers : one does not buy a book of this kind, for example, to be told (p. 331) that adequate drains must be provided, or (p. 320) that the bolts must be tightened once a month.

In summary, the book provides a large mass of information, some important, and some quite trivial, about all aspects of H.F. heating, but the treatment is unco-ordinated and unselective.

H. MARRIOTT.

Lighting Technique. By B. F. FEDOROV. Translated by W. R. STOKER, B.Sc.(Eng.), A.M.I.E.E., with additional sections by W. T. O'DEA, B.Sc., A.M.I.E.E. [Pp. 299, with 128 figures.] (London : Hutchinson's Scientific and Technical Publications, 1949. 25s. net.)

IN attempting to cover a very wide field, from fundamental concepts to the design of equipment and installations, considerable selection and compression had to be made ; the practice has suffered more than the theory. The translation is readable, although there are some inaccuracies and many of the terms used are not familiar in this country. Much of the data given refer to practice in the U.S.S.R. The treatment is essentially mathematical, but should not be outside the ability of the trained engineer.

The adoption of luminous flux instead of candlepower as the basic concept is sound for the engineer, although the unit is based on less well-established photometric data. The structure of the eye and phenomena of vision are adequately covered. The sections on light measurement, lighting fittings and illumination calculations are all better on the theory than on practice. The theory of electric lamps and the features to be considered in lighting installations are well reviewed, but tabulated recommendations and data on

practical lamps refer mainly to specifications in the U.S.S.R. Street lighting
is based on minimum illumination requirements, more in line with American
than modern British views, and the road surface brightness technique is not
mentioned. A.R.P. lighting is discussed on a rather theoretical basis. A
large number of exercises and a few laboratory experiments are included.

The principal features of tubular fluorescent lamps are well covered in the
additional sections ; fittings and installations are dealt with only briefly, but
the economics of fluorescent lighting are discussed.

● The title of this book may be misleading, as the book does not deal with
the technique of lighting practice as usual in this country ; however, it can be
read with advantage by anyone seeking knowledge of the theory of light
production, measurement and utilisation, or of practice in the U.S.S.R.

.   S. S. BEGGS.

Radio Engineering. Vol. II. By E. K. SANDEMAN, Ph.D., B.Sc.,
    A.C.G.I., M.I.E.E. [Pp. xxii + 579, with 192 figures.] (London :
    Chapman & Hall, Ltd., 1949. 40s. net.)

THIS volume includes chapters on interference and noise, radio receivers,
measuring equipment, feedback, network theory (using matrices) and filters,
followed by nine appendices, some of them lengthy. There is a useful biblio-
graphy of 1200 classified references, but the classification is rather haphazard.
For example, there is a section on " amplifiers—wide range " near the begin-
ning and a section " wide band amplifiers " near the end, with no cross-
references. There are separate sections on " the ionosphere," " propagation "
and " skip distance " with no cross-references.

Some of the chapters, such as that on measuring equipment, collect
together much useful information which has previously been scattered. As
in the first volume,* the emphasis is on B.B.C. methods, but there is less matter
of merely passing interest. There are some gaps in the presentation of the
subject, there being no information on microphones, loud-speakers or radio
propagation, and the treatment of aerial arrays is slight compared with that
of other subjects. Direction finding has a place in the chapter on interference.

The two volumes together give a wealth of information on various aspects
of telecommunications, presented in an original and interesting way by one
who is in close touch with practice. The second volume, like the first, is
well-produced, with a large number of clear and practical diagrams.

                                                        C. R. S.

Aerials for Metre and Decimetre Wave-lengths. By R. A. SMITH,
    M.A., Ph.D., A.M.I.E.E. [Pp. xii + 218, with 125 figures.] (Cam-
    bridge : at the University Press, 1949. 18s. net.)

THIS book, which is the latest addition to that excellent series of monographs
being produced under the general editorship of Mr. J. A. Ratcliffe, concerns
particularly aerial systems for operation within the band of wavelengths from
12 metres to 10 cm.

The author introduces his subject with a statement of the fundamental
laws governing radiation from a Hertzian dipole and then proceeds to build up
a comprehensive treatment of practical arrangements. He shows very clearly
how far the sinusoidal theory of current distribution in a linear aerial can be

* Reviewed in SCIENCE PROGRESS, Vol. 36, p. 745, Oct. 1948.

applied with reasonable accuracy and points with unmistakable emphasis to the different basis of calculation which is necessary in dealing with self-impedance or with radiators many wavelengths long. All this forms an admirable approach to the subject, coloured perhaps a little by the kind of treatment more familiar to the physicist than to the engineer. Having established principles, the author develops his theme with logical simplicity. Following a discussion of reflectors and directors he considers in turn normal types of transmitting and receiving aerials, long wire aerials, broadside arrays, Yagi aerials, aircraft aerials, wide-band aerials, slot aerials, aerials for deci-metre wavelengths and finally noise in aerials. The survey includes a number of matters not generally introduced into a book of this kind and there are some valuable records of experimental information published for the first time. This applies especially to the sections dealing with slot aerials and suppressed aircraft aerials.

There is, however, one feature of the book which tends to be confusing. This is the somewhat arbitrary use of symbols. Thus in the early pages r and x are employed respectively to represent resistance and reactance. Later on p. 13 these quantities become respectively x and y, symbols which in Chapter 7 both assume the significance of pure reactances. To add to the confusion x also frequently appears as a length in the usual way. Another example of the same thing is in the letter R which represents a distance in one place and a resistance in another. One is driven to the conclusion that there is no systematic plan in the allocation of symbols and sometimes little regard for customary usage in this matter.

In spite of that shortcoming there can be no doubt about the general quality of the book or its value to those wishing to study aerial systems of the kind discussed. The author clearly has a deep understanding of his subject and he presents it in a way that can only come from exceptional knowledge and experience in this field. The book is well illustrated and the usual high standard of the publishers is fully maintained.

H. M. BARLOW.

Tables Azéotropiques, Vol. I : **Azéotropes binaires orthobares.** By MAURICE LECAT. Second edition. [Pp. xvi + 406.] (Uccle-Bruxelles : Chez l'Auteur, 1949. Belgian Frs. 1000.)

THIS volume is a much-extended version of the compilation of boiling-point characteristics first published by the author thirty years ago. Over thirteen thousand pairs of components are listed in systematic fashion, the principal grouping being according to functional (organic) type, these types being taken in alphabetical order. Thus group 61 consists of alcohols-hydro-carbons, and its second table refers to ethanol and some two dozen hydro-carbons, the latter arranged in order of increasing boiling-point. The tables show the normal boiling-point of the second component B : the interval between it and that of A : the boiling-point of the azeotrope : the interval between the latter and the boiling-point of B : the weight per cent. of A in the azeotrope : an indication of the miscibility relations in the mixture : and references. Further information, such as the density of the azeotrope, the influence of pressure on its composition, etc., is given in footnotes to the tables.

A vast mass of valuable data, a great proportion of it determined by the author and his collaborators over a period of forty years, is thus made avail-

able in readily usable form. The work, whose significant place in laboratory and industrial operations with organic solvents needs no emphasis, is likely to form a standard source of reference for many years. Although uncut and paper-backed, it is excellently printed and has very complete indexes and tables of contents, besides an adequate explanatory introduction. A similar compilation for three-component systems is in preparation.

M. M. D.

Supersonic Flow and Shock Waves. By R. COURANT and K. O. FRIEDRICHS. Pure and Applied Mathematics, Vol. I. [Pp. xvi + 464, with 216 figures.] (New York and London : Interscience Publishers, Inc., 1948. 56s. net.)

THE rapid development of gas dynamics is a remarkable instance of the stimulation afforded by relation to practical possibilities. Many mathematicians who would otherwise have confined their activities to research in abstract mathematics have made great contributions. Important as this situation is for the mechanics of supersonic flight, it is no less important on purely scientific grounds. This is because much of the analysis involved in gas dynamics is of the non-linear type. Successful applications of mathematics to non-linear problems have been very limited, but it is essential to extend the scope of non-linear theory in order to tackle many very important subjects such as plasticity, relaxation phenomena and the like. The very substantial addition to non-linear techniques afforded by modern gas dynamics is therefore most useful.

The present book will surely be a classic, representing as it does the joint work of two masters of the subject. In such a case it is an advantage that the book carries the flavour of the authors' personal approach to the problems dealt with. The style throughout is elegant though severe. A reader versed in the notation and subject-matter of Lamb's *Hydrodynamics* would find it difficult to realise that this also is a book on a branch of the same subject : its notation and presentation of the subject-matter is so very different. So much so, indeed, that it is hard going for one who, while not contemplating research in gas dynamics, wishes to obtain a general idea of the method of treatment and the nature of and reasons for the results arrived at. For the really serious student, however, the book will be invaluable.

The first chapter summarises the hydrodynamical and thermodynamical equations necessary for the discussion of the flow of waves, while the second chapter is an excellent account of the mathematical theory of the hyperbolic differential equations which occur in the description of the flow. The third chapter deals with one-dimensional flow. Most of this chapter is concerned with the discussion of shock waves, one of the most important aspects of the subject. The remaining chapters deal successively with isentropic, irrotational steady plane flow, flow in nozzles and jets, and flow in three dimensions. The book is attractively printed with formulæ well displayed.

H. S. W. M.

Computation Curves for Compressible Fluid Problems. By C. L. DAILEY and F. C. WOOD. [Pp. x + 33, with 32 figures.] New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 16s. net.)

THE purpose of this collection of charts is to present graphically the numerical relationships which obtain in a number of cases of the flow of air at high

speeds. Some of the cases now commonly met in engineering applications are covered, namely the relationships arising from the energy equation and those applying in flows involving plain oblique shock waves, Prandtl-Meyer expansion, and conical shock waves. The charts cover flows at Mach Numbers up to 4·0.

The volume contains thirty-two charts, grouped in three sections, which are separated by finger index sheets for easy reference. The printing of the charts is not above criticism ; in a number of cases, the graticule used is such as to " glare " in the eye of the user, and in places symbols and figures are not easy to read owing to interference between them and the lines of the graticule, which are not interrupted for overprinting. Some of the data might perhaps be better presented in tabular form. Whilst the paper used is of fairly good quality, it is unlikely that the charts would long withstand repeated use, particularly as the method used to retain them within the cover is such that it is to be expected that they will easily be torn out.

The accuracy which can be attained in using the charts is likely to be sufficient for most engineering applications.

The charts are preceded by a thirty-three page section in which the theoretical relationships upon which they are based are derived, and the assumptions and limitations upon which they rest are stated. Whilst there is no new fundamental matter in this section, it is a compact and well-written exposition of the theory of the flows with which the charts are concerned.

The value of the ratio of the specific heats of air used in two of the sets of charts is 1·400, whilst 1·405 is used for the conical shock case ; the former value is generally accepted as the more correct, and it is not clear why 1·405 is used in one section. The errors involved in its use, however, will not be of importance in applications of the kind for which the charts are intended.

The collection is likely to be useful to those engaged in design or experimental work involving the flow of air at high speeds, and, though the presentation is open to criticism in some ways, the volume can be recommended as fulfilling a need.

A. A. HALL.

Gas Tables : Thermodynamic Properties of Air, Products of Combustion and Component Gases, and Compressible Flow Functions. By JOSEPH H. KEENAN and JOSEPH KAYE. [Pp. x + 238, with 5 figures and 64 tables.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1948. 40s. net.)

IT is but a few years ago that steam engines were designed without any reference to thermodynamics. The advent of the steam turbine, however, made a study of thermodynamics essential, and a natural corollary to this was a demand for reliable steam tables.

Recent developments have called for rather similar tables giving the properties of gases. The original edition of this text appeared in 1945 under the title of *Thermodynamic Properties of Air*. The new volume comprises some 64 tables. Very complete information is given of the standard gases, air, nitrogen, oxygen, etc., at low pressures and for the products of combustion of air and hydrocarbons. These tables have direct application in many modern problems, notably that of the gas turbine, and any means of reducing the time taken in analysing the thermodynamic cycle of such a machine is obviously worth while.

Another group of tables assists in the rapid calculation of polytropic processes and steady flow through nozzles and diffusers.

Other tables relate to one-dimensional isentropic compressible flow, normal shock functions and particulars for Rayleigh and Fanno lines.

Some 22 pages at the end of the book are devoted to a full explanation of the tables. The value of the work is considerably enhanced by the inclusion of numerical calculations showing exactly how the data are to be employed. Many of the tables are reprinted from official reports, such as *The Mechanics of Steady One-Dimensional Gas Flow*, which are not available to all readers. The corresponding theory has been published in the *Journal of Applied Mechanics*, to which full references are given.

Prof. Keenan has already proved himself to be the ideal author of such a work, for he is a recognised authority on the Properties of Steam. His co-author is also on the staff of the Massachusetts Institute of Technology, and one feels complete confidence in two such writers.

The whole volume is thoroughly workmanlike, and is as necessary to the internal combustion engineer as steam tables are to the steam engineer.

B. J. LLOYD-EVANS.

An Introduction to the Gas Turbine. By D. G. SHEPHERD, B.Sc., A.M.I.Mech.E. [Pp. xii + 387, with 174 figures, including 6 plates.] (London : Constable & Co., Ltd., 1949. 24s. net.)

IN the literature on the gas turbine there has been, until now, a marked gap between books of a descriptive nature and papers written by specialists. Prof. Shepherd, having had contact with both the research and manufacturing aspects of the turbine, is clearly in an ideal position to write the present text, in which he has steered a middle course. By presenting an introduction to the subject from the designer's point of view, he has done a great service to student and engineer alike.

Chapter 1 gives a concise digest of the relevant thermodynamics, except perhaps the section on polytropic efficiency, in which the meaning of adiabatic efficiency could be made clearer. The next chapter covers the general problem of the flow of gases. On p. 33 there is a definition of inertia which savours of momentum rather than inertia. One only of the various theories of the action of blading, namely the vortex, is given. Possibly this is merely following common practice.

Various cycles are next described and several graphs are given to show the effect of gas temperature on specific power, also the effect of intercooling and heat exchange. No mention is made here, however, of the effect of hydraulic friction in the exchanger, which may reduce the pressure ratio at which the heat exchanger ceases to be effective for a given maximum gas temperature.

The characteristics of compressors and the turbine proper, as developed at the R.A.E., are amply discussed in Chapters IV and V, and in the latter the all-important question of blade strength is handled.

Under the heading of combustion there is an excellent discourse on fuels, from both physical and chemical aspects, combustion chamber performance and flame phenomena. The chapter on heat exchange describes various tube arrangements and the transfer is adequately discussed from both the mathematical and practical points of view.

The last three chapters give an account of existing plants, development and test equipment.

Not the least valuable part of the text is the bibliography and the calculations for a complete cycle which are given in an appendix. Here the friction in the exchanger is taken into account.

There is no doubt whatever as to the general value of the book; it forms a first-class introduction to the subject.

B. J. LLOYD-EVANS.

Elements of Mechancial Vibration. By C. R. FREBERG and EMORY N. KEMLER. Second edition. [Pp. xiv + 227, with 179 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 30s. net.)

ONE of the main features of the so-called progress in engineering during the past fifty years has been a vast increase in the rotational speed of machines. There have been many attendant troubles, notably vibration. This is not only dangerous, as it may cause failure of material by fatigue, but it is always liable to affect human comfort, either by direct shaking or by the production of excessive noise.

The authors of the book under review are obviously masters of their subject. Not only do they present the material in a logical and readable form, but they have made this second edition of special interest by including a chapter on sound. The particular selection of worked examples and questions with solutions shows that they realise just what is required by a young engineer to bring home to him the full meaning of the theory. Whatever the source of the oscillations, he should have sufficient grasp of his subject to know how to reduce their ill-effects to a negligible amount.

The first three chapters cover the simple theory of vibrations without and with damping, also the action of forced vibrations with marked and small amounts of damping. Chapter IV discusses vibrations of systems with several degrees of freedom and introduces the tabular or Holzer method of solution, one commonly used in design offices.

Various methods of isolating and absorbing vibrations are given in Chapter V, while the next chapter explains the reduction of a complicated to an equivalent simple system which is more suited to calculation.

This is followed by a discussion of the vibration of beams—a further addition to the earlier edition. Unfortunately, no mention is made of the fact that Rayleigh's method is only applicable to the fundamental mode of vibration and not to harmonic modes.

As mentioned earlier, the authors have included a chapter on sound, its measurement, transmission and absorption.

The mobility method is a powerful tool for the solution of the more complicated vibrating systems, and Chapter IX provides an excellent introduction to this subject. Finally, there is a discussion of mechanical and electrical models of vibrating systems. The bibliography, although full, is drawn almost completely from American sources.

The practical side is kept to the forefront throughout, and the book provides an excellent elementary treatment of mechanical vibrations.

B. J. LLOYD-EVANS.

Engineering Laminates. Edited by ALBERT G. H. DIETZ, Sc.D. [Pp. viii + 797, with 331 figures.] (New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1949. 80s. net.)

To the British reader the title of this book may not immediately convey its scope, since the word laminate is not sanctioned by the *Oxford English Dictionary* as a noun. It serves admirably, however, as a general term for that large and increasing group of materials formed by glueing or otherwise intimately bonding together a number of separate sheets in order to obtain specific properties in the finished product. These properties may be strength, as in three-ply wood, which is probably the best known of the laminates; prevention of corrosion, as in certain aluminium-clad products where a central sheet of strong alloy is protected by two layers of aluminium; or resistance to chemical attack, as in glass-lined steel equipment used in various chemical engineering processes.

It is a composite work edited by Dr. Albert Dietz of Massachusetts Institute of Technology, and he has been most ably served by a team of experts in their own branches of the subject, who have each contributed a chapter. There are twenty-two of these chapters, and most of them relate to particular types of laminated construction. The first, by Prof. N. J. Hoff, deals with basic theory of sandwich-construction and laminates, and it is gratifying that British work in this subject is recognised; too frequently the Atlantic seems to act as an isolating medium in this respect. A general chapter on adhesives follows and lends emphasis to the importance of this element of the combination. Other chapters deal, in addition to materials already mentioned, with glued-laminated wood, wood-concrete, plastic laminates, hard surfacing by fusion welding, sprayed metal, sandwich construction, rubber laminates, etc. A concluding chapter describes the moulding and construction of laminates and sandwich materials.

Emphasis is placed throughout on engineering properties rather than on specific uses of the laminates, but sufficient descriptions of their applications are given to add further interest to the book. The volume is admirably produced and printed on paper which reminds us of those days when we also expected a book to be pleasant to sight and touch. A number of the chapters contain good bibliographies and the general index is excellent. The Editor, contributors and publishers are to be congratulated on a book of unusual quality and importance.

<div align="right">A. J. S. P.</div>

CHEMISTRY

An Advanced Treatise on Physical Chemistry. Vol. I: **Fundamental Principles, the Properties of Gases.** By J. R. PARTINGTON, M.B.E., D.Sc. [Pp. xlii + 943, with 269 figures.] (London, New York, Toronto: Longmans, Green & Co., 1949. 80s. net.)

THIS first volume, of a work planned to consist of three or four, is a magnificent feat of scholarship and learning. And it is very difficult to review: partly because few reviewers can have a sufficiently wide and detailed knowledge to criticise all its sections; and partly because the long and interesting Preface seems to anticipate all the general criticisms that might conceivably be made—and answers them.

The volume consists of seven sections: I (114 pp.), Mathematical Introduction (since the work is meant to be intelligible to the reader who, at the

outset, lacks even the Calculus) ; II (119 pp.), Thermodynamics ; III (59 pp.), The Kinetic Theory of Gases ; IV (84 pp.), Statistical Mechanics and Quantum Theory ; V (43 pp.), Wave Mechanics ; VI (126 pp.), Temperature ; VII (389 pp.), The Properties of Gases.

The general plan is to develop the theory in adequate mathematical detail and with historical notes ; then to accompany it with information on practical matters and with a great body of experimental data, not necessarily restricted to what current theory can accommodate. The book is certain to be useful to University students and teachers, to laboratory workers, and " to chemists and engineers engaged in large-scale work," both as an exposition of principles and also as a work of reference. In all sections where the reviewer is able to judge, or upon which he has been able to get a competent second opinion, the matter is eminently sound. In so large a book there are bound to be errors and misprints ; but the writer has been able to find very few, and none of a serious kind. The style is deliberately terse and the text much broken by mathematical equations. For these reasons some chemists will not find the book readable. Others will disagree, for the presentation is very clear, " the title ' Advanced ' referring to the size and scope of the work rather than to its difficulty." Undergraduates, for instance, will find much profitable reading, though they may need guidance as to where to leave off.

An unusual, and fascinating, consequence of Prof. Partington's plan is the juxtaposition of advanced theory and workaday laboratory detail. We turn from Heisenberg's matrix mechanics on p. 419 to thermoregulators (with about 150 references) on p. 420. On p. 511 we are told the price at which Nernst's assistant supplied an apparatus for preparing liquid hydrogen, and on p. 518 we embark on the theory of magnetic susceptibility. There are recipes for vacuum greases, and a discussion of gas degeneracy ; notes on the errors of thermometers, and an account of the history of the Second Law of Thermodynamics ; a presentation of London's theory of the van der Waals attraction, a description of methods for determining the critical temperature, a collection of empirical relationships for calculating critical constants, and tables containing the critical data for about a hundred substances. . . .

The price is high ; but so is the content of the book, which is likely to have a lasting value. All physical chemists who have handled this volume will be looking forward to the appearance of its successors, and wondering whether they can be as good as this.

Looking back at his attempt to deal with so large a book in so short a notice, the reviewer feels that he might have done better had he confined himself to quoting as much as possible of that long Preface, merely adding the opinion that the author has succeeded in his aims.

<div align="right">J. C. SPEAKMAN.</div>

Isotopic Carbon : Techniques in its Measurement and Chemical Manipulation. By M. CALVIN, C. HEIDELBERGER, J. C. REID, B. M. TOLBERT, and P. F. YANKWICH. [Pp. xiv + 376, with 107 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 44s. net.)

THIS is a unique book among the several recently published ones on tracer methods, as it is devoted entirely to methods encountered in work with the

carbon isotopes. The chapters of the book follow a logical sequence starting with a description of production and properties of C^{11}, C^{13} and C^{14}, followed by chapters on their measurement. C^{14} is probably the most useful of the carbon isotopes, but the rather low energy of its β-radiation necessitates special arrangements for its assay and sample preparations. It is quite natural, therefore, that greater attention is given to C^{14} in the book than to either C^{11} or C^{13}. The reader will find a choice of methods suited for most of the problems encountered with this isotope. The great care that has been spent on the chapter of sample preparations of C^{14} labelled material emphasises the importance of this aspect of tracer work with C^{14}. About one-third of the book is devoted to description of organic and bio-syntheses of the carbon-labelled compounds prepared up to the time of writing the book. The methods of syntheses are described concisely, yet with fair amount of detail. A special chapter deals with some degradation procedures for the identification of the position of the carbon label in certain compounds.

In 9 out of the 10 appendices special considerations are given to particular points of radioactive assay (statistical treatment of counting data, coincidence corrections, self-absorption data for C^{14}, etc.) and of vacuum techniques. In addition to references in the text (given as footnotes on each page), a complete bibliography of all published work with isotopic carbon up to 1948 will be found most useful in Appendix X.

The authors should be congratulated on the remarkable achievement of their co-operation. They have produced a laboratory manual of the greatest value to all workers using carbon isotopes. The exposition is clear throughout and the chapters are well balanced. This book is most warmly recommended.

G. POPJÁK.

A Textbook of Colloid Chemistry. By H. B. WEISER. Second edition. [Pp. x + 444, with 117 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 44s. net.)

On the cover of this book we read " . . . the whole field of colloid chemistry treated from the classical point of view. Illustrations of theoretical and applied principles are drawn from the modern as well as the classical work."

The reviewer is fully in agreement on the importance of a sound historical approach to colloid chemistry, but he would like to point out that the greatness of the classical work is not enhanced by ignoring, as the present author frequently does, the impact of advances in physical chemistry of the last twenty-five years. This undue reverence for the past may perhaps explain, although it does not justify, some major omissions, such as synthetic polymers and most of the last twenty years' work in colloid and surface chemistry.

The book abounds in out-moded theories and concepts : space precludes more than a few examples here :

p. 18. The apparent anomalies of the Gibbs adsorption isotherm are discussed in terms of concepts shown to be incorrect several years ago.

p. 154. The solution of polymers is referred to as " peptisation." No mention of the modern treatment of polymer solutions : the latest reference is 1926.

p. 162. The account of membrane permeability makes no reference to the Teorell/Meyer theory, now twelve years old.

p. 222. No mention of the zwitterion structure of proteins.

p. 223.   The account of colloidal electrolytes is a decade out of date and largely inaccurate, *e.g.* the statement that the micelle is " highly hydrous." The fact that salts such as sodium palmitate are strong electrolytes and hence fully ionised in solution does not appear to be appreciated.

p. 247.   Membrane equilibrium.   No mention of the modern work on protein solutions.

p. 272.   The statement that ions in the double layer " oscillate through considerable distances " can scarcely be reconciled with modern ideas of solutions.

p. 290.   The theory of " protection " given is incorrect, as are those for butter churning (p. 346), and for the action of glycerol on soap solutions (p. 354).

p. 293.   The stability of hydrophilic colloids is discussed in terms of " hydration shells " and Bancroft's theory (1926) of the effect of ions on the association equilibrium of water.   On p. 303 we read that coalescence of oppositely charged particles is opposed " by the elasticity of the water shells " !

p. 379.   Contrast the statement there ". . . the range of molecular attraction, which is of the order of $50m\mu$," with that on p. 55.

Another major criticism concerns diagrams, which in many places are badly needed if the reader is to make anything of the text.

The reviewer regrets that he could not recommend this book to anyone wishing to learn the fundamentals of colloid chemistry, and still less to anyone interested in the modern trends.

A. E. ALEXANDER.

The Colloid Chemistry of the Silicate Minerals.   By C. E. MAR-SHALL.   [Pp. x + 195, with 85 figures.]   (New York : Academic Press, Inc. ;   London :   H. K. Lewis & Co., Ltd., 1949.   43*s.* net.)

THE development of the study of clay and of clay minerals during the last quarter of a century has in more than one way been very scattered.   The subject has interested people with quite different occupations who, to some degree, have approached the subject independently :   moreover, the subject itself has been studied from different scientific angles without, in the early stages, any appreciable realisation of the intimate relation between them.

It is no easy task to gather together into one coherent account this diversity of work, retaining that which is vital to the story and rejecting that which is irrelevant.   Dr. Marshall, however, has succeeded admirably in his attempt to do this.   He is admirably qualified for the work because his own researches are diverse—associated with the relationship of the chemical and X-ray studies of clay minerals, their optical properties, the size, shape and coagulation of clay particles, and also with the attempts to find a mathematical relationship between clays and the solutions of electrolytes with which they react.   To this can be added that he has shown the same interest in all other phases of work on this subject.

Following the historical introduction there is a general introduction to silicate structures, which, with the following chapter on three-dimensional framework silicates, should be useful to those seeking a first knowledge of the subject.   Otherwise, however, this book must definitely be regarded as an advanced book, to be appreciated only by those who have a fairly full knowledge of the physical chemistry and mineralogy involved.

Almost inevitably some workers in this field have indulged in theoretical considerations and in experimental work on synthetic materials which have been rather dangerously assumed to behave like clay : it is therefore interesting to note that the author recognises the difficulties that may arise here and indicates where further and better-founded experimental work is required.

This book is published under the auspices of the American Society of Agronomy, as the first of a projected series of monographs. This first volume in the series will encourage every agricultural scientist to look forward to those that are to follow.

N. M. C.

Ion Exchange : Theory and Application. Edited by FREDERICK C. NACHOD. [Pp. xii + 411, with 124 figures.] (New York : Academic Press, Inc. ; London : H. K. Lewis & Co., Ltd., 1949. 64s. net.)

ION exchange is proving so versatile that there can be few, if any, chemical laboratories where it does not repeatedly offer advantages over older procedures. Consequently this, the first book on the subject, is sure of a wide welcome : it will be needed by all specialists in the field, and others should turn to it for indications of how modern exchange resins can assist in their own problems.

The book is edited by F. C. Nachod, and consists of sixteen articles written by American experts. It has to a high degree the merits and faults of this modern type of publication. Each chapter is up to date, comprehensive and well documented, and adequate cross-references from one chapter to another are given ; but there is no unifying principle, and no real concern for the reader—he is given the information in the literature, and a little more, and the process of digestion is left to him.

The theory of ion exchange is mainly dealt with in three articles, on " Ion exchange equilibria " by H. F. Walton, " The kinetics of fixed-bed ion exchange " by Henry C. Thomas, and " Fundamental properties of ion exchange resins " by W. C. Bauman. The last of these is a masterly though all too concise introduction to the subject, and the non-specialist is recommended to read this chapter before turning to the articles touching on his special interests. Then there are three important articles from members of the Permutit Company of New York on ion exchange equipment design, and its large-scale application in the problems of water treatment and sugar refining. Inorganic uses are covered by chapters on metal concentration and recovery (Sussman and Nachod), the separation of inorganic cations (Schubert) and analytical applications (W. Rieman III) ; biochemical applications are described by N. Applezweig and R. J. Block. To complete the contents there are short articles on de-salting sea water, on the possibilities of multistage operation, and on catalytic uses ; and finally a chapter on miscellaneous applications, which describes uses as diverse as the treatment of ulcers, the soilless growth of plants, and the modification of cow's milk for infant feeding.

An appendix lists the exchangers now available (in America), and the indexing is thorough.

C. W. D.

The Adsorption of Gases on Solids. By A. R. MILLER. Cambridge Monographs on Physics. [Pp. x + 133, with 38 figures.] (Cambridge : at the University Press, 1949. 12s. 6d. net.)

THIS volume is based upon the Cambridge Physical Tract entitled *Some Problems in Adsorption*, written by the late J. K. Roberts in 1938, but it is much more than a new edition of this work, as the greater part has been completely rewritten in accord with new ideas and new developments in this field. The practical aspects of the subject are almost restricted to a brief indication of the methods of measurement of accommodation coefficients and of heats of adsorption, but the book is most valuable in giving a concise summary of the theories relating to heat of adsorption and the kinetics of the formation of immobile and mobile adsorbed gas films. The theoretical aspects of the subject are illustrated, with particular reference to the kinetics of the production of atomic hydrogen at heated tungsten surfaces. The concluding chapter gives a good account of the modern treatment of dipole interactions between adsorbed particles.

This is not a book for the beginner in the subject, but those who have some previous knowledge of the subject will find it a stimulating summary, particularly of those aspects which have been studied at Cambridge during recent years. It is written in a lucid style and is well produced.

J. W. S.

Molecules and Crystals in Inorganic Chemistry. By A. E. VAN ARKEL. Translated by J. C. SWALLOW. [Pp. x + 234, with 45 figures.] (London : Butterworth's Scientific Publications, 1949. 17s. 6d. net.)

BASED on the third Dutch edition, this book is described in the preface as being intended for students in their first year of chemistry or medicine, but a fairly substantial knowledge of the inorganic chemistry of the commoner elements is assumed. After a general introduction to the electronic theory of valency, emphasis is concentrated on the heteropolar bond, and the effects of the ionic radii and ionic charges on the physical properties, crystal structures, and heats of formation of various classes of compounds are discussed. The influence of these factors in determining the direction of chemical reaction in substitution, double decomposition, and oxidation-reduction processes is also illustrated. The same considerations are then applied to the structures and stabilities of complex compounds, hydrates, and ammoniates, and to the strengths and stabilities of oxyacids and bases. The theory of dielectric polarisation is outlined, and the effect of dipole moment on boiling-point is stressed. The last chapter is devoted to a discussion of van der Waals-London forces, electron pair bonds, and the intermediate character of most actual bonds is emphasised. An appendix includes a brief treatment of colloids and adsorption phenomena.

As it is regarded as suitable for students at a stage where precision of statement is to be encouraged, it is a pity that the symbolism used is a little loose, since it is sometimes difficult to tell whether the atom, ion, or molecule of an element is intended. Thus when referring to the iodine and chlorine in KI and KCl they are written as I_2 and Cl_2, respectively (p. 88). Nevertheless, it is an interesting and stimulating approach to the subject, but it will probably be most valuable to a student who has already covered the themes discussed from the more conventional point of view.

The author and translator are both to be congratulated on the attractive style which removes the usually obvious traits of a translation.

J. W. S.

The Terpenes. Vol. II. By J. L. SIMONSEN. Second edition revised by SIR JOHN SIMONSEN, D.Sc., F.R.I.C., F.R.S., and L. N. OWEN, B.Sc., Ph.D., F.R.I.C. [Pp. xii + 619.] (Cambridge : at the University Press, 1949. 35s. net.)

To the study of the more complex natural products belonging to the caro-tenoid, steroid and polyterpenoid groups the chemistry of the monoterpenes constitutes an almost indispensable introduction. It is essential also that this fundamental chemistry should from time to time be revised in the light of new knowledge, and chemists in this field all over the world will be grateful to the authors for their recent efforts. This 600-page second volume, revised some eighteen years after the appearance of the first edition, deals with the dicyclic terpenes and their derivatives in six chapters embracing the thujane, carane, pinane, santene, camphene and fenchane groups. It is welcome news that a third volume dealing with the sesquiterpenes and diterpenes, the latter being included in this work for the first time, is in the press. It might be hoped that subsequently, when the chemistry is still further clarified, it will be possible to include the triterpenes. Much new material has been published in the intervening years and, as in Vol. I, many of the additions result from the application in the terpene field of recently developed physical and chemical methods. The high standard set in the earlier volumes has been admirably maintained, but some concession to the reader could have been made in the numbering of the structural formulæ. Thus, in the chapter on pinane, the section on α-pinane involves Roman numerals up to nearly 200, an unnecessary complication which tends to hinder rather than assist reference to the many beautifully set out formulæ.

E. R. H. JONES.

A Chemistry of Plastics and High Polymers. By P. D. RITCHIE, B.Sc., Ph.D., F.R.I.C. [Pp. viii + 288, with 34 figures.] (London : Cleaver-Hume Press, Ltd., 1949. 25s. net.)

IN this volume the author sets out to describe in comprehensive fashion the structural chemistry of polymers, and so approaches the subject from the Organic point of view. He deals with the principles of polymerisation and polycondensation, the important groups of polymeric materials (phenoplasts, aminoplasts, proteins, cellusoses, lignins, rubber, the drying-oil and the inorganic polymers, etc.), and various related topics. Although this is not the first book to describe the structures of industrially important polymeric materials, it is the first volume to attempt to describe systematically from a theoretical standpoint the chemistry of the whole field of polymer formation.

The book is a very readable and stimulating one, and in its various chapters is assembled an immense amount of information, all logically arranged to throw light on the fundamental types and processes of polymeric aggregation and in reasonable degree to trace the relationship between constitutional pattern and outstanding physical qualities. The chief merit, indeed, of the book is that it provides a broad survey of polymeric categories, mechanisms and phenomena, and their interrelations, and in so doing it meets a need that has been sorely felt in recent years by students desiring to qualify in the

chemistry of high polymers and plastics. For the latter purpose the book is very highly to be recommended.

The diagrams, formulæ and indexes are good, and such deficiencies as the reviewer recognises in the text are those of incompleteness in the systematic classification of polymer groups, due mainly to gaps in present-day knowledge. In just one respect, however, that relating to the classification of low molecular polymers, the treatment seems unnecessarily disconnected—sufficiently so to give the reader an impression of unpredictable or haphazard behaviour. The book forms an excellent introduction to detailed studies of reaction mechanisms and physical phenomena in the polymer field, and the author is to be congratulated on having produced a valuable work.

E. H. F.

Fundamentals of Synthetic Polymer Technology in its Chem·ical and Physical Aspects. By R. HOUWINK. Second edition. [Pp. xii + 258, with 194 figures.] (Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. 28s. net.)

THIS book is a revised edition of Dr. Houwink's *Technology of Synthetic Polymers*, 1947. The title has been altered to indicate the stress placed on the fundamental background in relation to technology. The alterations in the text are only of minor significance.

The book attempts to cover all synthetic polymers, including elastomers, plastics and fibres. It deals first with basic principles and then proceeds to give an account of the technology of materials. Such a treatment, within the space of 258 pages, leads to difficulties of presentation which the author has not satisfactorily solved. Neither specialist nor student is catered for adequately. The student, in particular, is likely to be left with a superficial knowledge. This is unfortunate, because the author is hardly correct in stating that none of the books so far published " has stressed the *basic principles* of this important subject sufficiently to enable the reader to understand its technological aspects " ; there have, in fact, been two or three comprehensive volumes published recently which have filled this need.

The style of writing is frequently so indifferent as to lead to ambiguity, and much more could have been done in editing the English (see, for example, the account of the formalising of casein on p. 214, which gives the impression that the process takes place in the press). There are, also, far too many errors of detail which would certainly mislead the student. Formulæ and chemical equations are sufferers in this respect, as on pp. 22 and 23 under phenolic resins and silicones, while the properties of materials are often incorrectly given. Thus Teflon softens at 327° C. (not 375° C.). Nylon can certainly not be moulded by injection at 150–200° C., neither is it reasonable to speak of all parts of the Nylon fibre equipment being maintained at temperatures above the melting-point of the polymer. The account of the vulcanisation of Neoprene, attributed to the reactivity of chlorine for hydrogen atoms, is another confusing section.

Despite its defects, the book contains considerable useful information, particularly in its references to recent publications. The author and subject indexes are adequate, even if it is surprising to note the absence of certain prominent British names. The general reader will benefit from the book, so long as he realises the existence of the kinds of pitfall mentioned above.

N. J. L. MEGSON.

Elastomers and Plastomers. Vol. II : **Manufacture, Properties, and Applications.** Edited by R. HOUWINK. [Pp. xvi + 515, with 225 figures.] (Amsterdam : Elsevier Publishing Co, Inc. ; London : Cleaver-Hume Press, Ltd., 1949. 52s. 6d. net.)

THIS is Vol. II of the series of books on Elastomers and Plastomers, edited by Dr. R. Houwink. The first volume (not yet published) is scheduled to deal with the fundamental aspects of high polymer chemistry and physics, and therefore the second is logically concerned with the more practical side of the manufacture and applications of high polymer substances. The wide ramifications of the subject make it absolutely necessary for the volume to be a co-operative effort among a number of experts. Here the problem that faces each author when confronted with writing adequately on the technology is to know where to stop. Although high polymer science has made striking advances, much of the technology of the manipulation of high polymers has been developed empirically, and therefore the constant endeavour of the industrial scientist is to effect a satisfactory fusion of the empirical and scientific knowledge. This might be said to be the general background against which the articles are written in this volume.

It is only to be expected that the technological specialist in his own field will know much more than is written in this book, but its primary object is to give a complete résumé in the space available of the methods used in the plastics industry as a whole. In this connection there are, in a number of the articles, photographs of the plant used in manipulating polymers, and in other places half-tone photographs of the products. Many of these illustrations do not really help to illustrate the matters being discussed. With plant, line diagrams showing the principles of operation would be much more helpful ; with the products the illustrations are better omitted, for the photograph usually gives no clue at all to the nature of the plastic and its application can be better described in the text. This is a book primarily addressed to those knowledgeable in high polymer science and technology.

It is difficult in a short review to mention all the articles separately. Dr. Houwink himself deals adequately with the phenol formaldehyde resins, while Dr. van Royen deals with a particular type of ion exchange resin, namely Wofatit. The urea and melamine resins have a chapter to themselves by G. Widmer and K. Frey. The ethylenic polymers, by H. T. Neher, occupy about a third of the volume, devoted to the thermosetting resins. The cellulose derivatives, by Dr. V. E. Yarsley, take a substantial fraction of space, the fibre side being given least prominence. The protein polymers are treated separately as plastics by A. D. Whitehead and S. H. Pinner, and as fibres by C. Diamond. The synthetic polyamides, by L. F. Salisbury, the silicone resins, by J. R. Elliott, and the alkyds, by J. R. Patterson, are all dealt with by people having direct contact with these resins in the organisations in which they were originated. The natural resins, I. C. Clare, and asphalts, R. N. Traxler, presumably because of their technological importance, are dealt with in some detail. Natural rubber is not considered, but its derivatives are dealt with in one chapter by Dr. T. R. Dawson, and Dr. Naunton deals very compactly with the whole subject of synthetic rubber in sixty closely packed pages. There is, therefore, a very wide range of topics, all dealt with by writers who have first-hand acquaintance with their subject. This gives authority to these highly compressed reviews. The book is excellently printed and illustrated.

H. W. MELVILLE.

Organic Coatings in Theory and Practice. By A. V. BLOM, Ph.D. [Pp. xii + 298, with 121 figures.] (Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. 36s. net.)

IT is fair to say that the organic coating industry belongs to the present century and the science which sustains it to the post-1918 period. One of the few men whose life span is contemporaneous with the rise of organic coating science is Dr. A. V. Blom, the author of this work. He knows what he wants to say and has said it in a very pleasant manner ; with the help of the publisher and the many excellent plates it is no exaggeration to describe the production as elegant.

In suggesting that Dr. Blom has been a long time deciding what to say (and to describe much of his own work) I mean only that here is the distilled essence of a life's work and experience written into a highly philosophical background. Here is the integration of theory and practice with familiar facts presented in terms of their true scientific import and new horizons in plenty.

The seven chapter headings well suit the style of treatment adopted, *viz.* :

1. *Fundamental considerations* which give opportunity to present in general terms the colloidal and macromolecular concepts, the meaning of plasticising action and the process of film formation.

2. *Natural*, and 3. *Synthetic film-forming materials*, which chapters provide a full and satisfying study of the appropriate materials.

4. *Physical*, and 5. *Chemical film-formation*, covering on the one hand all processes depending upon evaporation and congelation, and, on the other, processes in which the film is converted by oxygen, heat or chemical reaction. A logical system.

6. *Pigments*. The most significant work in this section is that concerned with the relationship between pigment and vehicle.

7. *Coating film properties and their testing*, grouped under rheological behaviour, mechanical features such as hardness, tack and adhesion, the influence of moisture on the behaviour of films, *i.e.* permeability, diffusion and swelling, optical methods of investigating stresses and structure of films (in which field Dr. Blom has made notable contributions) and finally, durability.

Here and there through the book errors can be found. Some of the arguments used lead to conclusions about which there may be legitimate differences of opinion—but it is that sort of book and personally I would decline to quibble.

' A good ending for this review is provided by the words with which Dr. Blom begins, *viz.* " The best for practice—a stringent theory." My opinion is that Dr. Blom has knowledge worth imparting to others and he has not only tried, but succeeded, in writing an admirable book.

<div style="text-align: right">L. A. JORDAN.</div>

Physics and Chemistry of Cellulose Fibres, with particular Reference to Rayon. By P. H. HERMANS. [Pp. xxii + 534, with 225 figures.] (Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. 57s. 6d. net.)

THE author of this most important book is the director of the Laboratory for Cellulose Research of the Algemeene Kunstsijde Unie at Utrecht. His aim is to marry together a mass of technical knowledge on which the stupen-

dous modern industry of artificial fibres is based and the results of academic researches into the chemical constitution of cellulose. The German occupation of Holland delayed the completion of the work and isolated the author during several very fruitful years in the history of cellulose research. As a result, the book misses many important contributions by British and American workers, but, on the other hand, these very workers will welcome the book because the author had access to German researches of the same period.

The book consists of three parts : Part I, 5 chapters, deals with the constitution, crystallinity, micellar structure, molecular weight, chemical behaviour and dispersion of cellulose. Part II, 8 chapters, covers the general properties of morphology, micro-structure, and physical and chemical behaviour of cellulose in the form of fibres. Part III, 18 chapters, is concerned with artificial cellulose fibres, and almost exclusively those obtained by the viscose process. Within this framework, the author presents a critical review of a mass of published work, balances the pros and cons of alternative interpretations and clarifies the issue where, in the past, the same terms have been used for different conceptions, such as the "micelle."

The book is undoubtedly for advanced workers. For others, it would have been a better plan to observe the old discipline of "experiment, observation and inference " or first the facts, then the speculations. The reader is at times left with the feeling that facts are disclosed only when they conveniently fit the argument. Thus, the simple fact, discovered by John Mercer, that treatment with caustic soda increases the absorptive capacity of cellulose for moisture and dyes is first brought in on p. 145.

A word of praise is well earned by Miss May Hollander for her able translation into English. The book is commendably free from misleading phraseology, though one notices on p. 333 the loose sentence " Alkali sulphite slows down ageing velocity " and the term " slack sodium cellulose " for what we should describe as " loose soda-cellulose." The proof readers have overlooked some misprints, especially in names (such as Chawdbury for Chaudhury), but few of them would prove a snare to the type of reader for whom the book is designed. The work of the printers will still be the envy of British authors. The Elsevier Publishing Company must be congratulated on the handsome series of books in which this is the second volume.

<div style="text-align: right">J. C. WITHERS.</div>

A Bibliography of Dyeing and Textile Printing. By L. G. LAWRIE, A.R.I.C. [Pp. 143.] (London : Chapman & Hall, Ltd., 1949. 15s. net.)

THE colouring of textiles has attracted man's attention since the earliest times and it is not surprising that the literature of the craft is considerable. Although most of the works essential to the modern dyer and research worker have been published in the last fifty years, many of the earlier writings are of interest, not only to the historian, but also to a large number of others who are fascinated by the subject and eager to know the secrets of dyers of the past. Mr. Lawrie's Bibliography provides a representative list of publications since 1510, and some 816 books are catalogued, being arranged in alphabetical order according to authors. There follows a short-title list of the same works in chronological order and a useful classified subject index of the books is also provided. The bibliography is not complete—the author does not claim that it is—but even though its publication date is 1949 there is no mention of books

published after 1946. Most of the information has been obtained from the catalogues of the more important technical libraries and from about 21 well-established bibliographies and book lists, including that of Jules Garçon published in 1893, the *Cumulative Book Index*, the subject index of modern works added to the library of the British Museum in the years 1881–1940, and *Bibliotheca Britannica* by Robert Watt (Edinburgh, 1824). Manufacturers' pattern cards which provide so much information on contemporary practice are not included, and yet several quite small and unimportant publications which are pamphlets rather than books are listed. The bibliography would have been much more useful if the name of the publisher of each entry had been given along with the author, title and other information. Perhaps it is too much to expect that in the case of old books the name of a library or institution possessing a copy might also have been given, but this information would have been especially valuable to the more serious student of the history of dyeing. The author frankly states that his collection is not intended for bibliophiles and consequently it is perhaps unfair to apply the usual standards in assessing the value of this particular bibliography. It is, however, unfortunate that the first list published for many years should not be comprehensive and should leave so much to be desired in presentation and arrangement.

C. S. WHEWELL.

Alcohol : A Fuel for Internal Combustion Engines. By S. J. W. PLEETH, B.Sc., F.Inst.Pet. [Pp. xvi + 259, with 61 figures, including 2 plates.] (London : Chapman & Hall, Ltd., 1949. 28s. net.)

FROM the title the prospective reader will expect to find within the covers of this book everything in reason about alcohols as fuels. In this he will not be disappointed.

He will also find a considerable amount of material which has been written up many times before in standard works on petroleum. For example, Chapter 3 deals at length with the internal combustion engine with little specific reference to the use of alcohol fuels. The same criticism may be made of Chapters 5 and 6 on " Knock and Knock Rating " and " Knock Rating and Engine Tests," and there is a general tendency to consider problems in relation to petroleum rather than alcohol fuels. This is perhaps excusable since alcohol is rarely used as a fuel except in blends with petroleum products.

In Chapter 8 the author has made some claims for alcohol in aviation fuels, but the fact remains that no civil or military aircraft anywhere in the world uses alcohol blended fuels.

The water tolerance of alcohol fuels is of great importance and more attention might perhaps have been given to this subject in the book. Ethanol blends are fairly well covered, but the difficulties associated with the use of methanol are given insufficient prominence.

For the rest, the style is lucid and considerable thought has been given to the layout. The book is well illustrated with graphs, diagrams and tables, is very easy to read and appears free from obvious errors. Each chapter contains a summary at the end and an extensive list of references.

The book is perhaps somewhat expensive at 28s.

D. L. SAMUEL.

Chemistry of Specific, Selective and Sensitive Reactions. By
FRITZ FEIGL, Eng., Dr.Sc. Translated by RALPH E. OESPER. [Pp. xiv
+ 740.] (New York : Academic Press, Inc. ; London : H. K. Lewis
& Co., Ltd., 1949. 97s. 6d. net.)

DR. FEIGL has spent a considerable amount of his academic career in the
pursuance of analytical chemistry, especially relating to the identification of
minute traces of substances. His school at Vienna was the cradle for teaching
the technique of identification, using spot methods, and the widespread
demand for his previous publication entitled *Spot Test Methods of Analysis*
is evidence of the universal appeal of this most useful adjunct to normal
methods of analysis. These books were of immense value to the practical
worker, and in fact they may be regarded as laboratory manuals.

The volume under review can be equally regarded as the theoretical
textbook on the subject, and is an attempt to explain the chemistry behind
so many of the reactions in use in micro-chemical analysis. This technique
has developed mainly during the past twenty-five years in depth and breadth
coincidental with the development of instrumental methods. It aims at the
identification and determination of the smallest amount of a substance in the
presence of other substances, using a minimum of time, material, and effort.
This presupposes maximum consideration of Specificity, Selectivity and
Sensitivity to analytical processes, and it is around this theme that the book
is written.

The book commences with a chapter concerning the characterisation of
tests by Specificity, Selectivity and Sensitivity, with emphasis on the limiting
proportions involved and the rôle of reaction conditions. Thus it is pointed
out that in even the most sensitive reaction the molecular concentrations are
relatively large (*e.g.* the catalytic reaction between silver and ferrous iron by
gold requires 150 million Au molecules per ml.).

In micro-chemical technique, great use is made of complex and co-ordina-
tion compounds. The chapter illustrating the theoretical aspects of these
compounds is extremely lucid and fully described. The work of Werner and
Pfeffer is detailed, with the application of the Residual Valency Theory to
explain complex ion formation, this being illustrated extremely fully with
reference to complexes like rubeanic acid, di-methylglyoxime compounds, etc.

Masking and de-masking reactions are given a close study. The function
of fluorides, boric acid, citric acid, metaphosphates, in preventing chemical
reactions is explained under this heading. Enhancement of Sensitivity is
described in detail, including the effect produced in this respect by complex
formations (*e.g.* the activation of boric acid by glycerol) and of course the
importance of catalytic actions in general in analytical chemistry.

The main chapter in the book concerns the effect of certain atomic groups
on Selectivity, and here is described the theory behind the use of most of the
organic reagents that have found their way into micro-chemical analysis.
This chapter includes an excellent description of Dithizone and its manifold
uses, and gives a rationale for the use of phenols, amino-acids, oximes and
nitroso groups, in metal analysis.

Another chapter deals with surface effects, *e.g.* colour, particle sizes,
suspendability, colloidal action, protective colloids, adsorption and capillary
action.

The final chapter is on Fluorescence and Photo-Reactions.

The book is an immense effort, and, although it inevitably tends to repeat

itself under the various classifications, is extremely readable and a mine of information to the practising analyst as well as to the student of organic chemistry.

R. F. M.

Modern Methods for the Analysis of Aluminium Alloys. By a Committee of Chemists convened by ALAR (The Association of Light Alloy Refiners). [Pp. viii + 144, with 11 figures.] (London : Chapman & Hall, Ltd., 1949. 13s. 6d. net.)

DURING the late war and the years immediately preceding it, the enormous demand for aluminium alloys to rigid specifications made it imperative for proper foundry control to employ methods of analysis of the utmost rapidity consistent with accuracy. The methods finally approved by the members of this Committee, after extensive trial in their own laboratories, have been collected together into the present volume in the hope that they may be of general interest in a wider analytical field.

As indicated by the title, emphasis in this book is on *modern* methods ; more than half of it is devoted to the application of physico-chemical instruments, while certain newer chemical techniques and reagents have been selected to replace old-established ones where they are more suited to analysis on mass-production lines.

Following a chapter on sampling, Part I deals with the determination of the usual alloying elements and impurities and Part II with some less common elements. In Part I there is a choice between chemical (gravimetric or volumetric) and photometric (absorptiometric) methods, but electrolytic and polarographic methods are recommended only where they are thought to offer a real, practical advantage over others available. Each method, which is designed for the determination of a single element from a separate weighing of the sample, includes a brief account of the principle involved, directions for varying the procedure when dealing with different types of alloy and an estimate of the time required by a skilled analyst. In certain circumstances it may be preferable to determine several constituents from a single weighing, and in Part III two composite photometric schemes are described.

There are ample references to the chemical literature, including the published methods of other firms in the aluminium industry both in this country and abroad.

F. R. E.

Progress in Metal Physics—I. Edited by BRUCE CHALMERS, D.Sc., Ph.D. [Pp. viii + 401, with 15 plates and 134 figures.] (London : Butterworth's Scientific Publications, Ltd., 1949. 45s. net.)

THE present volume is the first of an annual series that is intended to provide authoritative reviews of the state of knowledge in specialised aspects of physical metallurgy and metal physics. Such reviews, it is maintained, are necessary in view of the large and rapid advances now being made rendering it difficult for specialist research workers to keep in touch with progress in branches other than their own. Annual reviews are regular features of a number of scientific and technical journals. These generally comprise numbers of short reviews of the year's publications in particular fields. In contrast, in the present series it is intended that the necessary historical background should also be included the first time a particular subject is

treated and that relatively few subjects should be discussed rather fully in each volume. The title is thus somewhat somewhat misleading.

Dr. Chalmers' choice of subjects and collaborators for this first volume gives the series an auspicious start. They are : ' Progress in the Theory of Alloys," by Dr. G. V. Raynor ; " Theory of Dislocations," by Dr. A. H. Cottrell ; " Crystal Boundaries," by Mr. R. King and Dr. B. Chalmers ; " Age Hardening of Metals," by Mr. G. C. Smith ; " Hardening Response of Steels," by Messrs. E. H. Bucknall and W. Steven ; " Preferred Orientation in Non-Ferrous Metals," by Dr. T. Ll. Richards, and " Diffusion of Metals in Metals," by Mr. A. D. le Claire.

All the articles are clear, concise and free from serious omissions. Reference might, however, have been made to the theoretical and experimental work of Borelius' school in the article on age hardening, and the article on preferred orientations in non-ferrous metals would have justified its title better if matter other than for copper and the copper alloys could have been included. Apart from these minor criticisms, the enterprise which enables outstanding research workers to write such reviews cannot be too highly commended. Although such work is an additional demand on their time and energy, it should perhaps be regarded as a duty, and suitable provisions should be made to facilitate its discharge.

The book is well produced on good paper and well bound, and the price is perhaps not unreasonable bearing these features in mind.

A. B. WINTERBOTTOM.

Metallurgy for Engineers. By E. C. ROLLASON, M.Sc., Ph.D., F.I.M. Second edition. [Pp. viii + 339, with 179 figures.] (London : Edward Arnold & Co., 1949. 16s. net.)

WITH the growing realisation of the importance of metallurgical knowledge for engineers, numbers of books of scope similar to the present one appeared between the two world wars, particularly in England. Among these Dr. Rollason's enjoyed great and well-deserved popularity, as is witnessed by seven reprintings of the first edition since its appearance in 1939. The author is exceptionally well fitted to write such a book, in view of his extensive experience of teaching both technical college and university students on the one hand and of directing industrial metallurgical research on the other. Now that revision of the text has become desirable in view of many rapid developments during the last war, it is indeed fortunate that the author has been able to do this so expeditiously.

It is emphasised that the book is not intended for self-study, but as a concise factual summary to relieve students following a lecture course, in which the subject is provided with a detailed introduction and background, of much of the burden of note taking.

New matter includes : an account of brittle fracture of carbon steels and its relation to low-temperature properties and the impact test ; creep properties of jet engine and turbine materials, isothermal transformation diagrams for steels and the effects of alloying additions on those and on the hardenability as revealed by the Jominy test ; powder metallurgy ; sigma phase in stainless and gas turbine steels, revised diagrams for copper alloys ; references to the latest B.S. specifications for En steels and specifications for copper alloys and light alloys in draft at the time of writing ; a brief simplified treatment of the modern conception of the metallic state, crystallographic

terminology and ternary equilibrium diagrams. The sections on magnesium and on welding have been rewritten.

In such a small general book there is not room for extensive exposition of theories and theoretical controversies. Nevertheless, the author has frequently given a simple theoretical interpretation of phenomena described and thus provided a co-ordinating factor for the mass of factual information. The photomicrographs and diagrams are clear and well chosen, contributing effectively to the understanding of the text and reflecting credit on author and publishers.

A. B. WINTERBOTTOM.

Metals Reference Book. Edited by C. J. SMITHELLS, M.C., D.Sc., F.I.M. [Pp. xvi + 735, with numerous figures.] (London : Butterworth's Scientific Publications, 1949. 60s. net.)

RARELY is it that one finds enjoyment in studying a reference book of data, but this book is the exception ; the reader is fascinated right from the beginning, where in less than two pages is given in terse language a practical account of first aid in the laboratory. Although a relatively unimportant part of the book, this is worth noting because it seems to set a standard of straightforward language which is kept up throughout the book in the many parts which are explanatory. The clear mode of expression is a model of what scientific writing should be and reflects great credit on the editor and associate editors, whose task must have been heavy.

The value of a book such as this, however, stands or falls not so much by the mode of presentation as by its completeness and accuracy. If a reference book is bad in these respects it is generally obvious immediately ; if it is good it takes time to find out how good it is. Its completeness is certainly impressive ; its accuracy will be judged in the course of time. In compiling data there is often too much material at hand and it falls to the lot of those who write reference books to sit in judgment and select the best values. This is the most difficult part of the task and whatever is done is often open to question, but the list of names of contributors and editors is sufficient to inspire confidence.

A list of the subjects covered in this work would be tedious ; a list of those left undone would be extremely difficult to compile. In any case, the work is not merely a collection of tables ; it offers the facilities of a library assisted by a first-class librarian. To some extent it is also a practical handbook, particularly in the sections devoted to metallography and to plating processes.

Altogether it is an excellent book.

E. S. HEDGES.

A New Dictionary of Chemistry. Edited by S. MIALL, LL.D., B.Sc., and L. M. MIALL, B.A., F.R.I.C. Second edition. [Pp. x + 589.] (London, New York, Toronto : Longmans, Green & Co., 1949. 60s. net.)

THIS work is a second edition of the one-volume dictionary of 1940, compiled by the late Dr. Stephen Miall with the assistance of 27 collaborators. It comprises some thousands of brief scientific and biographical articles, and is intended to serve as a compact work of reference for the numerous people— chemists, physiologists, druggists, doctors, etc.,—whose work demands clearly written and accurate information on a wide range of chemical matters. The

original articles, which include explanations of terms used in chemistry and chemical engineering, accounts of many chemical substances, chemical operations, drugs, vitamins and other bodies of biochemical importance, have been revised and considerably increased in number.

The production of a one-volume dictionary covering the wide domains of chemistry and able to meet successfully the occasional needs of a very varied public represents no very easy task. The articles must reasonably well cover the field (and therefore must necessarily be concise), but they must not fail to convey quite definite and worthwhile information to all the grades of readers. The compilers seem to have exercised commendable discretion in the selection of their topics, and have produced articles characterised by a high degree of clarity of meaning and accuracy of exposition. The work is, therefore, as free from mystifying technicalities, specialist jargon, and vagueness of meaning as skilled and thoughtful effort can make it. The justification for diluting the chemical themes with brief biographical articles on a somewhat arbitrarily selected group of the world's living and dead chemists is not very obvious ; but, nevertheless, the net result is a work of reference, well printed in an attractive style, which can be recommended.

E. H. F.

GEOLOGY

Historical Geology. By CARL O. DUNBAR. [Pp. xii + 567, with frontispiece and 350 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 40s. net.)

THIS book provides an excellent introduction to the study of Historical Geology. The first four chapters focus the attention upon those features of rock arrangement and constitution which throw light upon the passage of time, changing climates and crustal movements. In like manner they show how fossils may be used as indicators of periods of time and of life conditions as well as guides to the progress of living things through the ages. For readers whose knowledge of biology is limited an appendix on the classification of animals and plants is provided.

The systematic study of earth history opens with a rapid survey of the place of the earth in the solar system and the universe, and of the more acceptable views concerning the origin of the earth itself. This leads on naturally to a brief consideration of the very fragmentary records of those vast periods of time referred to collectively as Precambrian, which make up no less than three-quarters of the whole of geological time. As the records of the remaining quarter become progressively less scanty they provide material for fourteen chapters dealing with the major periods in succession. Each chapter includes two main sections. One deals, first, with the geography of the North American continent in early, middle and late parts of the period. The details are then filled in by a description and a physiographic interpretation of the vertical and lateral changes in the nature of the rocks for the more important areas. The other deals with the life forms of the period. Minor sections are interspersed, dealing as occasion demands with other topics of interest, such as the history of geological discovery, problems of climate, vulcanicity and earth movement, the origin of land life, the emergence of mammals and of men.

The whole story is succinctly and vividly told and the reader is fortunate

in having such a delightful introduction to the subject.   The book is superbly illustrated with an abundance of pictures, sections, block diagrams and maps, carefully selected and well executed.

<div align="right">H. H. S.</div>

A Student's Introduction to Geology—mainly Physical. By GEORGE MACDONALD DAVIES. [Pp. viii + 246, with 175 figures.] (London : Thomas Murby & Co., 1949.   18s. net.)

THIS moderately priced textbook should be owned by all beginners in geology. It is lucidly written, and, although much condensed, contrives within its 246 pages to expound the important principles of the subject, British examples being quoted where possible.   The book opens with a short discussion on the scope of the science, followed by cosmical geology, geological time, the various kinds of rocks, earthquakes, volcanoes, geological structures, mountains, ground water, springs, rivers, lakes, the sea, ice, wind, heat, frost and rain.   The last part of the book (7 chapters) deals with stratigraphy, the study of fossils, and ends with a brief summary of the geological history of the British Isles.   This section, although very concise, is one of the most successful parts of the book.

Chapter 14 on section drawing is devoted to the study and description of geological maps and, by quoting index numbers of Geological Survey maps which illustrate typical structures, encourages the student to browse among maps for himself, warning him the while about the mistakes beginners usually make.

The treatment is adequate for Intermediate B.Sc. standard, and reading lists follow each chapter.   The illustrations are all line blocks which vary greatly in quality, possibly because they were done " by a number of different hands."

The elimination of " turgid or nebulous writing " by brevity sometimes leads the author to epitomise rather than expound.   Chapter 17 on lakes reads more like revision headings than an exposition for beginners.   Again, the reader meets new terms and mineral names which are not explained nor formulæ given ; for example, " pleochroic haloes " (p. 8) will prove a stumbling block to many, and the term " porphyry " is not adequately explained by Fig. 6 (p. 17), which needs a fuller legend.   Indeed, many of the figures would gain in value if the legends were somewhat expanded.

Errors are rare.   The reviewer saw only one letter omitted.   In Fig. 95 (p. 107), " thickness " should read " vertical thickness."   The type is pleasing and clear and the index is good.   A short glossary would be useful.   There is no doubt that this book will become a well-known text in schools and colleges.

<div align="right">ALAN STUART.</div>

BOTANY AND AGRICULTURE

The Cytoplasm of the Plant Cell. By A. GUILLIERMOND.   Translated by L. R. ATKINSON. [Pp. x + 247, with 152 figures.] (Waltham, Mass. : the Chronica Botanica Co. ; London : Wm. Dawson & Sons, Ltd., 1941 (second printing, 1948).   40s. net.)

WITH the increasing interest in the cytoplasm by virtue of its own special contribution to heredity and as the vehicle of the expression of nuclear heredity, a critical account of the structures in the cytoplasm is particularly valuable.

The book is a translation of an unpublished French manuscript, written by a pioneer investigator in this field. The present volume is a second printing reproduced by offset and consequently reproduces the misprints of the first issue published in 1941.

The study of the cytology of the cytoplasm has suffered in comparison with that of the nucleus. Basically there is the difficulty of finding an experimental approach. The cytoplasmic constituents do not possess distinctive morphological features by which they might be recognised at recurrent phases of the cell cycle. A considerable gulf exists between the description of cytoplasmic constituents and their relation to the physiological activities and heredity of the cell. The study is also confused by the protean forms, often given different names, that each of the distinguishable categories may show, so that each may mimic the others at some stages. There is also the difficulty of characterising the structures microchemically ; indeed, in this respect, some statements in the present volume are unduly optimistic.

Prof. Guilliermond presents a detailed account of the interrelations and distinctions of the various constituents. He recognises two kinds which are transmitted by division from cell to cell, and which can apparently be propagated only from pre-existing similar bodies or their primordia. Of these, the plastids are distinguished by their ability to bear chlorophyll in green tissue and to elaborate carbohydrates. They are derived from small bodies very similar in form and histochemical constitution to the chondriosomes, the other kind of autonomous structure. The chondriosomes remain minute, but may be granular (mitochondria) or filamentous (chondrioconts), and their function is unknown.

Other recognisable structures in the cytoplasm are considered to be secreted by the vital processes of the cell. The vacuolar system consists of fluid cavities, containing crystalloid and colloid substances, which are represented in embryonic cells by minute thread-like colloidal progenitors. Although almost always represented in plant cells and capable of fragmenting, the vacuoles seem to arise *de novo*—it is supposed by secretion of the cytoplasm.

There are two discouraging complexities in cytoplasmic cytology. One is the multiplicity of terms, the other the numerous conflicting interpretations and speculations. Guilliermond has done something towards reducing the former, but there is still an excess ; the inclusion of a glossary and synonymy would have been helpful. Guilliermond has done his best to reconcile the interpretations of different authors. However, the aggregate impression is that the purely cytological approach is rather sterile and that real advances in identifying the structures in which particular cellular activities are located will come from other directions.

D. G. Catcheside.

Botanik der Gegenwart und Vorzeit in culturhistorischer Entwickelung. By Karl F. W. Jessen (1864). [Pp. xxii + 495.] (Waltham, Mass. : Chronica Botanica Co. ; London Agents : Wm. Dawson & Sons, Ltd., 1948. 48*s*. net.)

This is the first of the " Pallas " reprints of scientific classics which are no longer available. To most botanists of to-day Jessen's History is known only by a single reference in Sachs' History, which was published in 1876, eleven years after that of Jessen. Jessen was born in 1821 in Schleswig, from 1851 to 1877 he was professor at the Agricultural College at Eldena (Vorpommern),

and he died in Berlin in 1889. Botanists interested in the history of science will welcome this reprint, for Jessen's History is different in many ways from that of Sachs ; it is notable for its cultural approach, as is indicated by its sub-title—*Ein Beitrag zur Geschichte der abendländischen Völker.*

<div align="right">V. H. B.</div>

The History and Social Influence of the Potato.   By REDCLIFFE N. SALAMAN, M.D., F.R.S.   With a chapter on " Industrial Uses," by W. G. BURTON.   [Pp. xxiv + 685, with frontispiece and 108 figures, including 34 plates.] (Cambridge : at the University Press, 1949. 50s. net.)

THE author of this work was formerly Director of the Potato Virus Research Station, Cambridge, from which post he retired in 1939. His years of retirement have been used to assemble a vast amount of information concerning the potato and its social influence and to present, in a very readable form, a book which, as a history of the potato and, indeed, of certain aspects of agriculture, will long be a standard work of reference.

In the early chapters, Dr. Salaman deals with the plant in its native home. The antiquity of the interest of man in the potato is determined largely by archæological evidence based on pottery. The crop was grown in South America two thousand years ago and probably many centuries before that. As is well known, Dr. Salaman does not accept the Russian theory that the European potato came from Chile or Chiloe. He advances reasons for supposing that it originated at the northern end of the Andean Range. Most of these reasons appear cogent, but the one based on the reaction of bolters to length of day is not convincing.

Dr. Salaman dates the introduction of the potato into Europe (Seville) at the latest in 1570. He discusses at some length the introduction of the potato into Britain and sets out clearly all the information that is available on this subject. However, he would be the last to deny that much of this information is speculative and that the original introducer of the potato into this country will probably never be known. It is possible that unrecorded voyages were made in the Sixteenth Century and, indeed, there may have been about that time more than one introduction.

The chapter on varieties—past, present and future—contains much that is interesting. Here Dr. Salaman describes his own—probably the earliest— attempts to breed Blight-resistant varieties. It is true that Dr. Wilson of St. Andrews used *S. demissum* for breeding over 40 years ago, but his objectives were not defined. In discussing synonyms and the part played in their elimination by the Potato Synonym Committee of the National Institute of Agricultural Botany mention might have been made of the contributions of the Scottish Scheme for the Inspection of Growing Crops of Potatoes which in a quiet way did much to eliminate the mischievous practice of using synonyms.

In describing the effects of the cultivation of the potato in Europe, Dr. Salaman's main thesis may be described in his own words : " The potato can, and generally does, play a two-fold part : that of a nutritious food, and that of a weapon, ready forged for the exploitation of a weaker group in a mixed society." According to him the potato in Ireland proved the most perfect means for maintaining the poverty and the degradation of the people. To use his words again : " In Ireland, it became a weapon of defence of a conquered people against their masters, as well as the instrument by which the

latter achieved the most complete exploitation of the workers. In this sinister capacity, it proved an efficient instrument whilst the age-old cleavages, racial, religious and social, offered an ideal field for its use." It is, however, possible that the author's description of the conduct of the English in Ireland is too severe. The chapters dealing with the Irish history certainly do not make pleasant reading. Apparently the potato played a somewhat similar, although less calamitous, part in the degradation of the common people of England and Scotland. After reading these descriptions, the reader will pass, in welcome relief, to the history of the potato in Tristan da Cunha.

The catastrophe that awaits a nation depending for its livelihood on such a plant as the potato is graphically described in those chapters which deal with the great Blight epidemics, particularly those in Ireland, which occurred in the middle of the nineteenth century.

In an appendix dealing with the failures of the potato crop in Ireland the author sets out a table in which possible causes are given. In this table, Blight is mentioned for the first time in 1845 and failures before this date are ascribed to various causes, including Blackleg, Bacterial Rots, Dry Rots, *Botrytis cinerea* and frosts. To the reviewer, it appears almost impossible that such widespread epidemics could have occurred so suddenly, without previous warning, and to him it would appear to be much more reasonable to assume that the Blight organism had been parasitic on potatoes in Europe for a considerable period before the epidemics occurred. It is certainly curious that epidemics of Blackleg and *Botrytis cinerea* are not mentioned after 1845.

The author has consulted an enormous number of references, over 800 being mentioned. It cannot be said, therefore, that he has spared himself in endeavouring to ascertain the truth. One curious omission is the *Transactions of the Highland and Agricultural Society of Scotland* which certainly mentioned potatoes in its early issues.

The book is much the most comprehensive and authoritative work on the history of the potato and is therefore sure of a wide welcome.

T. P. McI.

Freedom from Want : A Survey of the Possibilities of Meeting the World's Needs. A Symposium edited by E. E. DE TURK, Ph.D., for the American Association for the Advancement of Science. [*Chronica Botanica*, Vol. XI, No. 4, pp. 207–84, illustrated.] (Waltham, Mass. : The Chronica Botanica Co. ; London : Wm. Dawson & Sons, Ltd., 1949. 16s. net.)

THE symposium herein reported had, as its general background, the discussions of the F.A.O. and other organisations concerning the relative rate of increase of world populations and that of food supplies. H. R. Tolley, in a discussion of this point, concludes that world-wide collaboration can achieve a satisfactory balance. By intensifying the use of existing cultivated areas and by bringing fresh land into systematic production, R. M. Salter argues that food supplies could be doubled by 1960. The improved production of food crops during the past 50–70 years is quoted by K. S. Quisenberry as evidence that with further investigation and international co-operation the crucial problem of feeding the increasing world population can be solved. In considering current systems by which scientific investigation of agricultural problems are now carried out, M. A. McCall enters a plea for the quicker and more efficient translation of research data into practical terms and, especially,

for its more rapid utilisation in farm practice. J. D. Black introduces still another aspect of the matter by discussing relationships between the general level of nutrition and standard of living and variation in populations, *i.e.*, the effects on birth- and death-rates. The concept of an optimal population is presented; approach to this optimum may be facilitated by technical developments in agriculture and is associated with increased food consumption, increased output of work per head of population and with a general rise in the standard of living. The efficiency of animals in producing human food is discussed by F. B. Morrison. Milk and dairy products are regarded as of prime importance in food economy and in efficiency of production : eggs and pig products are placed next in order of importance, with beef and lamb production also ranking high.

The symposium affords interesting and sometimes provocative reading. The numerous factors concerned in the matching or balancing of food output and growth of population are introduced clearly and the difficulties are made apparent. Authors of the series of papers, however, share the view that the problem is not insoluble and that intensive scientific effort and world-wide co-operation are essential to the achievement of success. It is pointed out (R. M. Salter) that " science may discover and point the way, but it cannot dictate. The full measure of success in economic, social and political action comes only with the will of the majority : not from the desires of one group."

A. G. POLLARD.

Farm Work Simplification. By LAWRENCE M. VAUGHAN, Ph.D., and LOWELL S. HARDIN, Ph.D. [Pp. xii + 145, with 49 figures.] (New York : John Wiley & Sons, Inc.; London : Chapman & Hall, Ltd., 1949. 23s. net.)

TIME and motion studies to expedite business operations have been developed (particularly in America) during the last 20 years, and this is the first book of its kind to apply these studies comprehensively to farm operations.

There are three principal and related factors involved : the purely human factor, illustrated in the simplest possible way by using two hands instead of one, and by arranging the amount of walking a man has to do to avoid unnecessary retracing of the same tract ; the use of equipment designed to curtail labour and to produce quicker and sometimes better results ; the general organisation of all the various operations involved in the industry of farming in order that they may dovetail with a minimum time loss.

The first part of this book is written primarily for farmers and those working on the land. It illustrates what is meant by farm simplification and the savings that can be effected in pig farming, in dairy farming, in hay-making and with tobacco, fruit and vegetables. Here the book is able to show that certain types of routine work can be effected in a third, or even a quarter, of the time that was once taken.

The second part of the book is written primarily for those who wish to develop the study of the subject and deals with the methods of research to be adopted in work simplification. It concludes with some account of training and the holding of courses in this work.

The subject of this book is probably more easily applicable in America than in this country, and it is probably more useful to those young in the industry than to those long established in it. The important thing, however, which the authors fully realise, is that these studies convey general ideas

which those working on the land may use according to their own individualities and interests, and if it is treated in this way, with a full recognition that the human factor involves something more than organised routine, it should be interesting to all agriculturists and of considerable economic value to a vast number of them.

N. M. C.

The Soil and the Sea. A Symposium edited by TREVOR I. WILLIAMS. [Pp. 240, with 8 plates.] (London : The Saturn Press, 1949. 10s. 6d. net.)

THE purpose of this little volume of biological essays is to provide an interesting account of recent research and also to " provoke discussion and thought on the opportunities for benefiting mankind which are inherent in biology." In his introduction the Editor, Trevor I. Williams, points out that the importance of biological science is not so widely appreciated as it should be ; " for every pound that is spent on biology a score is spent on physics." And so he has collected a team of well-known experts who have produced eighteen short essays dealing with their special subjects. As might be expected, a number of them deal with agriculture, and one of the most interesting is by Sir J. A. Scott Watson, our foremost exponent of agricultural science to farmers and their advisers, who gives a concise and lucid summary of recent progress. A special branch, the possibility of using growth-regulating substances in crop production, is ably discussed by Richard Clements ; if a later edition is called for, the work of R. L. Wain at Wye should be included. A certain amount of overlapping with the chapter on Weeds by W. E. Brenchley and H. C. Long was perhaps inevitable. The sea provides some interesting chapters : D. T. Gould describes the experiments on fertilising the waters of Loch Sween with nitrates and phosphates which resulted in an increased rate of growth of the fish, and makes out a good case for further work on a larger scale : incidentally the results suggest that the discharge of sewage effluents into the sea may not be as wasteful as is often supposed. Those perennially interesting animals, whales, are ably discussed both by L. H. Matthews and C. M. Yonge ; and Julian Huxley has a stimulating essay on Species and Evolution which will also serve as a helpful guide to the non-expert.

In view of the large amount of information contained in the book, there should have been an index, and it would further have been helpful if the references had been given to the more important papers quoted, and also the initials of the investigators. But these are minor defects easily remedied in another edition : the essays fulfil their purpose of arousing interest and provoking thought, and the book can be strongly recommended to experts and laymen alike.

E. J. RUSSELL.

BIOLOGY AND MEDICINE

Comparative Anatomy. By LEVERETT A. ADAMS and SAMUEL EDDY. [Pp. viii + 520, with 364 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 40s. net.)

THIS book, though written for courses in American Universities, would serve for any degree course in Zoology. Very sensibly the first part of the book is devoted to a survey of the classification of the Chordata, which clarifies the

position of the vertebrates in the phylum. In addition to a review of the diagnostic characters of the vertebrates, mention is made of the various theories of their ancestry. In the chapter on embryology notice does not seem to have been taken of Conklin's work on Amphioxus.

The second part follows the usual sequence in a comparative treatment, and only a few points can be touched upon here. It is interesting that teeth are considered quite properly under the integumental system. The introductory section to the skull could have been made clearer. For example, chondrocranium and neurocranium are used as if they were synonyms, whereas some authors regard the neurocranium as that part of the skull surrounding the brain and chondrocranium as neurocranium plus the sense capsules. Also " skull " is used indiscriminately to mean cranium or cranium plus visceral skeleton.

In the vascular system there would be difficulty in visualising the development of the heart without some aid from figures. The general treatment is comprehensive and the diagrams of circulations are a useful addition to the more usual figures of arterial and venous systems.

The treatment of the nervous system and sense organs is naturally very condensed, but the essential differences in the telencephalon of amphibians, reptiles, birds and mammals would have been clearer if the changes in the pallium had been elaborated, and particularly the development of the neopallium, culminating in the relatively enormous mammalian cerebral hemispheres. In a comparative study it is this aspect which is important.

An extensive bibliography is appended and the provision of a comprehensive glossary is to be commended, for the complex nomenclature of vertebrate anatomy is often a sore obstacle to the new student.

The figures are clear and well labelled. However, in Fig. 64 the basement membrane might have been labelled to emphasise that the epidermis is a stratified epithelium ; the indication lines of the " sense capsules " in Fig. 84 go to the " sense organs " and not to the capsules ; the legend of Fig. 242 should be arterial " system " and not circulation, as there are no arrows to show the direction of flow.

A. J. G.

Principles of Biological Assay. By C. W. EMMENS, D.Sc., Ph.D. With a foreword by SIR PERCIVAL HARTLEY, C.B.E., M.C., D.Sc., F.R.S. [Pp. xvi + 206, with 25 figures.] (London : Chapman & Hall, Ltd., 1948. 21s. net.)

THE first applications of statistical methods to biological assay—that is to say, to the evaluation of substances by their effects on living organisms or surviving tissues of living organisms—was made by pharmacologists. In this field the names of Gaddum and Trevan are rightly held in high esteem by many whose approach to the problems has been that of the analytical chemist rather than of the biologist. In specialised fields, Burn, Coward and others have contributed to the subject, but they all had to learn their statistical technique and apply it to their biological problems.

Meanwhile a group of professional statisticians, inspired by R. A. Fisher's pioneering work in agricultural science, and having among them well-known experts such as Yeats, Finney and Fieller in this country, and Bliss and Snedecor in the U.S.A., were approaching the scene from the statistical side. The meeting of biologist and mathematician over the wider domain of pharma-

cology has been no less fruitful than is the more restricted and utilitarian plot on which biological assay is carried out. Here Dr. Emmens has already made a name for himself, and this book will much increase it. There is, however, less discussion of " principles " than its title would lead one to expect. True, they poke their awkward heads up from time to time, but the main aim of the book is to explain to the bio-assayist the statistical procedures that he must use to get the maximum of information from his tests and, to what Dr. Emmens holds to be the necessary extent, also the mathematical basis of those procedures. Thus the emphasis of this book is on the numerical aspect of biological assay—the way to get an answer to the question " How active is this sample ? " and the probability that the answer would be the same in replicate assays.

There thus still remains to be written a monograph on the more theoretical aspects of biological assay in which might be discussed such questions as the bias given to a result by " eliminating " from the animals used in a test those dying or falling sick during its progress. It would also be useful to indicate how the procedure of a biological assay may be in part at least determined by the extent to which either of two principle objectives is its aim, the comparative measurement of a physiological or pharmacological property on the one hand or, on the other, the estimation of the amount of a substance (or group of substances) for which chemical or physico-chemical methods of analysis are unavailable.

Though Dr. Emmens has not written such a book, it is indeed a tribute to the penetrating nature of his own exposition that in reading it one is led parenthetically or even only by implication to speculate on these rather different questions. One's satisfaction with his efforts is enhanced by its careful and neat appearance, meticulous production (printer's errors are substantially absent) and reasonable price. Apart from an occasional clumsiness—" Methods of making such adjustment and of allowing for differences which may be found to exist which are more statistically acceptable will be described later on " (p. 57) is hardly a model of elegant prose !—the book is written in a simple and clear style that materially assists the reader to follow what is often a very difficult line of thought for those comparatively new to the subject.

<div align="right">A. L. BACHARACH.</div>

Symposium on the Use of Isotopes in Biology and Medicine.
[Pp. xiv + 445, with 11 plates and numerous figures.] (Madison : the University of Wisconsin Press, 1948 (second printing, 1949). $5.00.)

THIS is the printed account of a symposium held at Madison during the week of September 10, 1947, on the biological uses of stable and radioactive isotopes. The volume has been reprinted within a year of its first publication and this fact speaks well for its popularity and general usefulness. In the second printing the rather large numbers of typographical errors of the first printing have been corrected, otherwise the text is unaltered.

The most distinguished scientists of the North American continent have taken part in the symposium, nineteen of whom have each contributed a comprehensive article on some aspect of research with isotopes. Dr. Urey, apart from his description of the methods used in the separation of stable

isotopes, has also contributed, towards the end of the volume, a stimulating article on the international aspects of atomic energy and on problems especially connected with its control. Farrington Daniels, in the last article in the book, discusses the possibilities of peace-time applications of atomic energy. Apart from the six more technical papers on the preparation and measurement of stable and radioactive isotopes by H. C. Urey, S. T. Seaborg, P. C. Aebersold, A. O. Wier, C. D. Coryell and M. D. Kamen, the other articles are concerned more strictly with the biological and medical applications of isotopes. In these, each contributor reviews the results obtained in a particular field of animal metabolism with the aid of isotopes. Thus, the metabolism of proteins is reviewed by David B. Sprinson, the intermediary metabolism of carbohydrates by Harland G. Wood and the intermediary metabolism of lipids by Konrad Bloch. Their articles give a clear picture of the present position of each problem.

The articles on metabolic studies with tracers are introduced by a description of syntheses of some organic compounds labelled with H, N, C and S isotopes by Donald D. Melville.

David M. Greenberg has contributed a discussion on the metabolism of mineral elements as studied with radioactive tracers, with particular reference to the metabolism of the bone salts in health, in rickets and in healing bone fractures.

The application of radioactive iodine to the study of thyroid metabolism is reviewed by I. L. Chaikoff and A. Taurog, both of whom have contributed much to the subject by their original researches.

This symposium is distinguished from most of the publications on biological applications of isotopes in presenting an extensive discussion on the medical uses of radioactive isotopes, and those interested particularly in this aspect of isotopes will find the three articles by Joseph G. Hamilton, Byron E. Hall and Saul Hertz of great value. There are but few comprehensive articles of such nature available at present. Dr. Hamilton introduces this subject by a more general article on studies of human physiology and biochemistry. Further, he outlines how radioactive tracers can be used advantageously as a prelude to therapeutic applications of the radioactive elements. The use of P^{32} for the treatment of blood diseases (polycythæmia vera, leukæmia and allied diseases) is reviewed by Byron E. Hall, and the treatment of thyroid disease with radioactive iodine by Saul Hertz. These articles give a very clear picture of what has already been done in this field. While it is too early to predict the ultimate results, yet in the case of polycythæmia vera, sufficiently large numbers of patients have already been treated with P^{32} to form the opinion that the advantages of this form of internal radiation therapy outweigh the risks involved.

A further excellent feature of this symposium is the liberal space allotted to the discussion of the health hazards involved in the use of radioactive isotopes and of the measures necessary for the protection of personnel and property.

This volume will serve as a useful reference work. The aim of the publishers was speed in publication and therefore the unattractive form of printing and a lack of general index may be excused.

G. POPJÁK.

Pharmacology and Toxicology of Uranium Compounds. Edited by CARL VOEGTLIN, Ph.D., and HAROLD C. HODGE, Ph.D. [Pp. xviii + 1084, in two parts, with 375 figures, including 13 coloured plates.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 85s. net.)

THIS volume, one of the United States National Nuclear Energy Series, records the results of work carried out during the war, mainly at the University of Rochester Medical School. It is presented in seventeen chapters, each contributed by different authors, preceded by a general introduction by one of the editors (Dr. Hodge) setting out the salient points and main results of the investigation. The work covers the chemistry of uranium ; analytical and statistical methods ; pathological anatomy and characteristics of uranium poisoning ; toxicity to animals when administered by injection, by feeding, by application to skin and eyes, and by inhalation ; distribution and excretion; acquired tolerance ; biochemistry of uranium in the animal body ; and studies on human exposure to uranium compounds.

Uranium in the body tends to become oxidised to the hexavalent state, and in this form it is an extremely potent kidney poison, causing degenerative changes in the tubular epithelium. Of the different routes of entry by far the most dangerous, industrially, is the respiratory tract. A major problem in this investigation was the measurement of the size of uranium dust particles in air, upon which the rate of absorption and therefore the relative toxicity so largely depend. An instrument called the " cascade impactor," devised in this country for the sampling of coarse aerosols, was redesigned for use with fine uranium dusts. In the cascade impactor air is drawn through a combination of jets of different dimensions, and impinges upon sampling slides, on which the dust particles are collected and their size distribution determined under the microscope. A difficulty here is the smallness of many of the particles, which makes it necessary to use a mounting medium of very high refractive index. Selenium has a refractive index of 2·8 and good optical clarity. By distilling selenium in a vacuum apparatus and condensing the vapour upon the slide holding the dust particles, these can be coated with a perfectly transparent and highly refractive film which greatly extends the optical resolving power of the microscope. This work on inhalation toxicity tended to confirm the safety limit, which had been tentatively adopted, of 0·15 mg. of uranium per cubic meter of factory air, a figure of the same order as those now accepted for lead and mercury.

Other points of particular interest include the complexing of hexavalent uranium with the carboxyl group of proteins and with bicarbonate and citrate, and the absence of any reaction with the sulphydryl group ; the extreme differences in susceptibility of different animal species, which make it difficult to assess the safety limits for man ; the rapidity with which uranium is excreted, especially after bicarbonate infusion ; and the eventual recovery of kidney function after removal of the toxic agent.

The treatment of the subject has been very thorough. Nearly 200 workers seem to have been actively connected with the project from its inception in 1943. They have established our knowledge of the toxicology of uranium upon a thoroughly sound basis and have made a most valuable contribution to industrial hygiene.

G. W. MONIER-WILLIAMS.

PHILOSOPHY AND HISTORY OF SCIENCE

The Freedom of Necessity. By J. D. BERNAL, M.A., F.R.S. [Pp. xii + 437.] (London : Routledge & Kegan Paul, Ltd., 1949. 18s. net.)

THIS book collects together some thirty-two essays, written over the last twenty years, and arranged in eight groups, each group being provided with a short introduction. The first and last groups expound some of the ruling ideas of the book by elaborating the " fertile concept of dialectical material-ism " (p. x) ; the other groups are concerned to show how, through such a Marxist interpretation, " the unity of the sciences amongst themselves, and their further unity with social processes " (p. 334) is to be understood, so that in the present world-travail there can be discerned " a new civilisation being born out of the ruins of the old " (p. xi).

Professor Bernal makes five major points :

(1) An important transformation of human society is now occurring.

(2) Modern science " by its own development " (p. 380) is no longer an " individual," " haphazard " affair, but demands an economic and political organisation.

(3) Such far-reaching organisation is given by a Marxist interpretation of all events.

(4) True freedom for the individual is gained when this interpretation provides his perspective on the world.

(5) If everyone so arranges their work and lives there will come a " far better and freer world than we have ever known " (p. 90). Unlimited progress would be secured (cf. p. 3).

Let us note, first, some of the important truths in these contentions : Many would agree in condemning the Cartesian separatism, which gave birth on the one hand to the dispassionate scientist studying an " objective " world, and on the other hand, with Locke's help, to the sturdy and isolated individual, with which most bourgeoisie political and economic theory is concerned. Many would agree that society cannot be given such an individualistic analysis, and that " integral organisation and democratic initiative " are not " irre-concilable opposites " (p. 57). Science, like the Post Office, might well be rationally organised without necessarily hindering all initiative (p. 291). Many would further agree that the ideally static Cartesian universe must be replaced by one in which change and activity is ultimate, where " process is reality " (cf. pp. 370–5). No theist, least of all a Christian theist, would weep at the passing of a deistic teleology. And an Incarnational religion will applaud time and time again Prof. Bernal's demand for a full and integrated life (pp. 150, 151).

All this means that most readers will not doubt that some radically new world-view is required by contemporary science and history alike, but will rather ask themselves whether Prof. Bernal's interpretation, while having much to commend it, is ultimately satisfactory and adequate. So let us mention certain difficulties that seem to arise.

The organisation of science is clearly meant to be coterminous with political boundaries. But the present political divisions lead, then, to some puzzles. E.g. while we are urged (p. 313) to have " planned utilisation of science for peace," we are on the same page urged, in Great Britain, not to rely on " foreign subsidies," but only on " full scale application of science." But surely science must be organised beyond national boundaries ? Or does

Prof. Bernal's qualification arise because he sees no hope in organising science *westwards* ? Yet, without *world* organisation of science, will there be world peace ? If our Marxist perspective seems *in fact* to have no likelihood of becoming *universal*, why should we suppose it to lead to *world* organisation and peace ? Either it demands world domination or it is as much a piece of wishful mysticism as Prof. Bernal attributes to some of his fellow-scientists.

Again, what of the "freedom of necessity" ? To serve God may be claimed to be perfect freedom, because we may suppose the organised community to exist within the perspective of God's mind. By the same sort of requirement, Prof. Bernal sees that, on his view, it must be possible, if ignorance is slavery, for all who are free to have a fully extended perspective (*see* (3) and (4) above). But in fact is this possible ? Prof. Bernal is rash enough to believe it is. "Once rid of vested interest in ignorance, it is perfectly possible, at any time, to provide a general picture " (p. 26). For professors ? For undergraduates ? For the "workers " ? I wish I could be so optimistic. Further, whether the unlimited progress (*see* (5) above) is by the conscious efforts of "free " agents (who never seem to exist till progress is finished) or by individuals yielding themselves to an "impersonal dialectic evolution " (a metaphysical "myth " if any is) is a puzzle which Prof. Bernal does not even begin to solve.

Prof. Bernal thinks his greatest enemies to be religion and "mystical " science. Certain interpretations of religion and popular science may be enemies for all of us. But does this exclude the possibility that we may yet justify a metaphysical use of words which is *not* superstitious. Even Prof. Bernal, as we have seen, is not free from metaphysical concepts of Hegelian portentousness—his Marxian analysis is offered as an *explanation*, not just as a tentative and summary description, *e.g.* p. 380. Why should we not look, then, for a metaphysics which would give us a world-perspective, a verbal map, both empirical and speculative (a "theory " in the sense admirably summarised on pp. 97, 98) ? Such a theory would have to do justice to the complexities of human nature, scientific method, political and economic theory, which Marxism, no less than Descartes, over-simplifies. If it could possess the truths for which Prof. Bernal contends, all the better ; if it could not, all the worse for it.

For if this book contains prejudices, exaggerations, political curiosities and some philosophical shallowness, it also contains a critical insight, a comprehensive vision and a prophetic urgency. Prof. Bernal would rid us of outworn doctrines of religion and science alike, and those who disagree with his alternative must produce another, and quickly. To read this book sympathetically is a most useful prolegomena for the task.

I. T. R.

The Origins of Modern Science, 1300-1800. By H. BUTTERFIELD, M.A. [Pp. x + 217.] (London: G. Bell & Sons, Ltd., 1949. 10s. 6d. net.)

PROF. BUTTERFIELD's book is a commentary on the movement which he regards as the distinctive feature of modern history. The book is made up of two main strands, one being the study of those scientific classics which have transformed Western scientific ideas, and the other, discussion of the effects of the movement thus brought about on the thinking of Europe. These two themes are naturally not taken in complete separation, though in Chapters

9 and 10, dealing with the transition to the *Philosophes* movement, and the place of the scientific revolution in the history of Western civilisation, the historian stands aside from the work of discussing and expounding scientific thought, and considers its influence in general.

What makes this book original and of quite first-rate importance is perhaps not so much this study of the wider influence of the scientific ideas (momentous though this influence was), but rather the exposition by a historian, who yet fully grasps the scientific principles involved, of Copernicus, *De Revolutionibus Orbium*, of Gilbert, *De Magnete*, of Harvey, *De Motu Cordis*, of Descartes, *Discourse on Method*, of Newton, *Principia*, and of Boyle, *The Sceptical Chymist*. In this series of great books, Prof. Butterfield sees the growth of modern science happening, and unlike most of the historians of science studies this growth at first hand in them. He does indeed more than that. There is, for instance, a brief, but most illuminating, account of the relation of Harvey's work to that of his Paduan predecessors. But the core of the book lies in its analysis of the scientific ideas of these giants.

No two views of the ideas that are the key to modern history would coincide. It might be argued that we should take the survey back to the twelfth century, and consider the growth of the Universities, and in particular the beginnings of nonconformist speculation, if we wish to trace its real origins. Prof. Butterfield is indeed at his best in explaining the Aristotelean and medieval theories of movement. But the things which made these theories possible were, in the first place, the development of a thinking society—no period is so intellectual as the later Middle Ages—with the expression of that development in the founding of the Universities, and secondly the recovery of some of Aristotle's work. At the other end of the story, we should dearly have liked a chapter on Darwin. The "unification" of physics is studied with the discoveries of Newton : the unification of chemistry with Lavoisier : perhaps most important of all has been the attempt to unify the picture in biology made by Darwin, and Prof. Butterfield's lectures lead up to this attempt, but end before it. We now seem to have reached yet another stage, when the validity of these systems of unification is necessarily questioned ; and the problem of the present is to consider how far their schemes can still be sustained. But that clearly is another matter—a matter not for the historian, but for the prophet.

WALTER OAKESHOTT.

A New Survey of Science. By WALTER SHEPHERD. [Pp. 512, with 256 figures, including 35 plates.] (London : George G. Harrap & Co., Ltd., 1949. 15s. net.)

THIS is a revised and enlarged edition of the author's book *Science Marches On*, published ten years ago. It is suited to the general reader, and it presents an account of the growth, present attainments and ideals of science, conceived as a single human activity. Stress is laid upon the many factors, intuitional, æsthetic and purposive, which play a part in the acquisition of scientific knowledge.

It is difficult to do justice to the wealth of information which the book contains, much of it only recently acquired and not yet easily accessible. Each chapter carries the story of some branch of the subject from the primitive stage to the latest developments. Tracing first the growth of writing and printing, the author deals next with the quest for the control of heat. He

then devotes several chapters to the discovery and utilisation of the mineral and chemical resources of the Earth, the exploration of its crust and atmosphere, and the revelation of its past history. From geology we pass to speculations on the origin and nature of life, to evolution and the curiosities of experimental genetics, and so to the working of the human machine in health and disease. A chapter on the Fascination of Figures introduces the second half of the book, which deals more conventionally with the pure physical sciences and with their technical applications to the control of materials and of forces. The rôles of classification and of measurement in the creation of science are discussed under the heading of Pigeon-Holes of Knowledge, and there are chapters on Weather Wisdom and the Science of Mind. The book ends upon a rather unusual note with a discussion of the new fields of speculation opened up through psychical research.

The original edition of the book has been well revised, but there are several small points which might be noted for future correction. In Tycho Brahe's cosmology (p. 313), the Earth was conceived as entirely motionless ; *Frascator* (p. 205) would be more correctly spelt Fracastor ; and the date of Chester More Hall's invention of the achromatic lens was about 1733 (p. 287).

<div align="right">A. A.</div>

MISCELLANEOUS

The Principles of Scientific Research. By PAUL FREEDMAN, B.Sc., M.I.E.E., F.I.E.S. [Pp. 222, with 11 figures.] (London : Macdonald & Co., Ltd., 1949. 15s. net.)

THIS book is intended to help young graduates in their early struggles to learn how to carry out research. In a brief but admirable foreword, Dr. J. W. T. Walsh points out the need for such a book. Some students " are likely to fall into the tragic error of assuming that if they obtain good honours degrees they are, *ipso facto*, well qualified for a career as a research worker " and even feel that they will have little more to learn. Moreover, an increasing number of people, in Industry and Government Departments, while not trained for or engaged in scientific research, have control over scientists, and they little realise how fatally easy it is for them to paralyse the efforts of even the best scientists under them.

Mr. Freedman endeavours in the first three chapters to define the terms " science " and " research " by showing how the principles which now form the basis of scientific method have evolved since Thales of Miletus. Though interesting, this part of the book is the least satisfactory and it contains some views on the work of some early scientists with which few of us would agree. Many readers would be better stimulated by a more concise exposition of the aims and methods of scientific research, with references to other books which those interested might consult with profit. (It is a criticism of the book as a whole that there is practically no bibliography.) These three chapters do show, however, the interaction between a scientist and the society in which he lives.

The remaining eight chapters are concerned with the mental approach of a scientist, the planning and organisation of research, the general conditions for experimentation, accuracy and economy of effort (including the use of statistical methods), and the patrons of research. As a whole, the book deals with research and development in the physical and chemical sciences in Industry, since the author very properly draws mainly on his own

experience, but many of Mr. Freedman's precepts and remarks apply equally well to research in Research Associations, Government Establishments and in Universities. Very few experienced scientists will quarrel with the advice given to young recruits and executives, and by no means all of them would have given such advice so clearly and convincingly. Mr. Freedman is at his best when basing his arguments and examples on his own experience, and it is enjoyable as well as instructive to read these sections of the book.

<div style="text-align: right">F. A. V.</div>

Science in Liberated Europe. By J. G. CROWTHER. [Pp. 336.] (London : the Pilot Press, Ltd., 1949. 18*s*. net.)

THIS book is based upon visits to France, Denmark, Holland and Czechoslovakia in 1946. Its contents fall broadly into three categories : (*a*) notes on University departments and other scientific institutions, the personalities in them, and their experiences under German occupation, (*b*) accounts of scientific work done by numerous scientists, and (*c*) accounts of the organisation of scientific work and of scientists in the four countries.

The unfortunate consequences of the post-war delays in book production are nowhere more evident than in this book, which is essentially topical, but, making full allowance for this, it must be said at once that the book does nothing to enhance the author's reputation. It is divided into four parts dealing with the four countries, and the sub-division (except of the French part) is also mainly geographical, but the individual chapters are nearly formless and give the impression of being taken almost verbatim from the author's original notes. Thus, although the book contains much interesting information, there is a good deal of tedious repetition (*e.g.* the continued restatement by successive French scientists of the need for more financial support for scientific work), some contradictions, and no attempt at synthesis.

The descriptions of scientific work have naturally suffered most by the lapse of three years between writing and printing, since nearly all of it has now been described in the scientific journals, but in any case the desirability of putting journalistic accounts of current scientific work into permanent book form is questionable ; apart from any other consideration, the record of an opinion about an unfinished research given in conversation (especially with a non-scientist having a different mother-tongue) may differ substantially from the scientist's considered judgment on the finished work, and may do him serious injustice.

The author appears to have gained his knowledge of the conditions of life in German-occupied territory and of resistance activities almost entirely from the interviews recorded in this book and to have lost his sense of proportion at the same time, so that he writes with an uncritical naïveté which is sometimes almost ludicrous. To emphasise these shortcomings, his style, while sometimes pedantic (" They (Dalton and Mendel) were both celibates and autodidacts "), and sometimes fifth-form (" Culture is not just Greek and Latin—it includes history, tradition and science "), is seldom pleasing, and the proof-reading has been perfunctory. Remembering the author's earlier books one is tempted to suggest that the literary researcher of the future will have more reason than the celebrated German student of Homer to take the view that this book was written not by J. G. Crowther but by another man of the same name.

<div style="text-align: right">E. G. COX.</div>

BOOKS RECEIVED

Extrapolation, Interpolation, and Smoothing of Stationary Time Series. By Norbert Wiener, Professor of Mathematics, Massachusetts Institute of Technology. Published jointly by The Technology Press of the M.I.T., and John Wiley & Sons, Inc., New York ; London : Chapman & Hall, Ltd., 1949. (Pp. x + 163.) 32s. net.

Introduction to Topology. By Solomon Lefschetz. Princeton Mathematical Series. Princeton, N.J.: Princeton University Press ; London : Oxford University Press, 1949. (Pp. viii + 218, with 74 figures.) 32s. net.

The Variational Principles of Mechanics. By Cornelius Lanczos. Mathematical Expositions, No. 4. Toronto : University of Toronto Press ; London : Oxford University Press, 1949. (Pp. xxvi + 307, with 22 figures.) 42s. net.

Theoretical Hydrodynamics. By L. M. Milne-Thomson, Professor of Mathematics in the Royal Naval College, Gresham Professor in Geometry. Second edition. London : Macmillan & Co., Ltd., 1949. (Pp. xxiv + 600, with 4 plates and numerous figures.) 60s. net.

Mechanics, Statics and Dynamics. By Merit Scott, Professor of Physics, The Pennsylvania State College. New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. (Pp. xii + 394, with 251 figures.) 38s. 6d. net.

The Face of the Moon. By Ralph B. Baldwin. U.S.A.: University of Chicago Press ; Great Britain and Ireland : Cambridge University Press, 1949. (Pp. xiv + 239, with frontispiece, 17 plates, 26 figures and 24 tables.) 40s. net.

Our Sun. By Donald H. Menzel. The Harvard Books on Astronomy. Philadelphia : The Blakiston Co. ; London : J. & A. Churchill, Ltd., 1949. (Pp. x + 326, with frontispiece and 178 figures.) 21s. net.

The Atmospheres of the Earth and Planets. Papers presented at the Fiftieth Anniversary Symposium of the Yerkes Observatory, September, 1947. Edited by Gerard P. Kuiper. U.S.A.: University of Chicago Press ;. Great Britain and Ireland : Cambridge University Press, 1949. (Pp. viii + 366, with frontispiece, 16 plates, 91 figures and 36 tables.) 60s. net.

Practical Physics. By Sir Cyril Ashford, K.B.E., C.B., M.V.O., Hon. LL.D., M.A., sometime Assistant Demonstrator at the Cavendish Laboratory, Senior Science Master in Harrow School and Headmaster of the Royal Naval Colleges of Osborne and Dartmouth. Cambridge : at the University Press, 1950. (Pp. xii + 175, with 61 figures.) 10s. 6d.

Molecules in Motion. By T. G. Cowling, M.A., D.Phil., F.R.S., Professor of Applied Mathematics, the University, Leeds. London : Hutchinson's University Library, 1950. (Pp. 183, with 27 figures.) 7s. 6d. net.

A General Kinetic Theory of Liquids. By M. Born, F.R.S., and H. S. Green. Cambridge : at the University Press, 1949. (Pp. viii + 98, with 2 figures.) 10s. 6d. net.

Dynamics of Real Fluids. By E. G. Richardson, B.A., Ph.D., D.Sc., Reader in Physics, King's College, Newcastle-on-Tyne. London : Edward Arnold & Co., 1949. (Pp. viii + 144, with 96 figures, including 2 plates.) 21s. net.

The Measurement of Air Flow. By E. Ower, B.Sc., A.C.G.I., F.R.Ae.S., Bramwell Medallist, formerly Senior Scientific Officer in the National Physical Laboratory, and Principal Scientific Officer in the Ministry of Supply. Third edition. London : Chapman & Hall, Ltd., 1949. (Pp. viii + 293, with 101 figures and 21 tables.) 30s. net.

Theoretical Aspects of Pressure-Pattern Flying. Compiled by J. S. Sawyer, M.A. Meteorological Reports No. 3. London : H.M. Stationery Office, 1949. (Pp. 64, with 24 figures and 6 tables.) 1s. 3d. net.

Cosmic Ray Physics. By D. J. X. Montgomery. Based on Lectures given by Marcel Schein at Princeton University, with special contributions by Shuichi Kusaka and Niels Arley. Princeton, N.J. : Princeton University Press ; London : Oxford University Press, 1949. (Pp. viii + 370, with 15 plates, 96 figures and 24 tables.) 40s. net.

Colours and How We See Them. By H. Hartridge, M.A., M.D., Sc.D., M.R.C.P., F.R.S., Director of the Vision Research Unit of the Medical Research Council and Professor of Physics at Gresham College. London : G. Bell & Sons, Ltd., 1949. (Pp. xii + 158, with 12 coloured plates and 39 figures.) 15s. net.

Sight, Light and Efficiency. By H. C. Weston, Director of Group for Research in Occupational Optics and Secretary of the Vision Committee, Medical Research Council. London : H. K. Lewis & Co., Ltd., 1949. (Pp. xiv + 308, with 132 figures.) 42s. net.

Fluorescence and Phosphorescence. By Peter Pringsheim, Argonne National Laboratory, Chicago. New York and London : Interscience Publishers, Inc., 1949. (Pp. xvi + 794, with 219 figures and 140 tables.) 120s. net.

Spectroscopic Properties of Uranium Compounds. By G. H. Dieke, Professor of Physics, the Johns Hopkins University, and A. B. F. Duncan, Associate Professor of Chemistry, University of Rochester. National Nuclear Energy Series. New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. (Pp. xviii + 290, with 25 figures and 73 tables.) 23s. 6d. net.

Electron Microscopy : Technique and Applications. By Ralph W. G. Wyckoff, Laboratory of Physical Biology, Experimental Biology and Medicine Institute, National Institutes of Health, Bethesda, Maryland. New York and London : Interscience Publishers, Inc., 1949. (Pp. x + 248, with 202 figures.) 40s. net.

Practical Microscopy. By L. C. Martin, D.Sc., A.R.C.S., D.I.C., Professor, and B. K. Johnson, D.I.C., Lecturer, in the Technical Optics Department of the Imperial College of Science and Technology. Second edition. London and Glasgow : Blackie & Son, Ltd., 1949. (Pp. x + 124, with frontispiece and 90 figures, including 10 plates.) 6s. 6d. net.

Magnetism. By David Shoenberg, Ph.D., Lecturer in Physics, University of Cambridge. London : Sigma Books, Ltd., 1949. (Pp. x + 216, with 8 plates and 56 figures.) 10s. 6d. net.

Artificial Radioactivity. By P. B. Moon, F.R.S., Professor of Physics in the University of Birmingham. Cambridge Monographs on Physics. Cambridge : at the University Press, 1949. (Pp. x + 102, with 28 figures and 5 tables.) 12s. 6d. net.

Ionization Chambers and Counters. By Bruno B. Rossi, Professor of Physics, Massachusetts Institute of Technology, and Hans H. Staub, Professor of Physics, Stanford University. National Nuclear Energy Series. New York, Toronto, London: McGraw-Hill Book Co., Inc., 1949. (Pp. xviii + 243, with 140 figures and 11 tables.) 19s. 6d. net.

A Symposium on Electronics in Research and Industry. Edited by A. G. Peacock. London: Chapman & Hall, Ltd., in collaboration with the Scientific Instrument Manufacturers Association of Great Britain Ltd., 1949. (Pp. xiv + 199, with numerous figures.) 16s. net.

Electricity in the Service of Man. By Sydney G. Starling, B.Sc., A.R.C.Sc., F.Inst.P., sometime Head of the Department of Physics in the West Ham Municipal College. Revised by H. J. Gray, M.Sc., LL.B., A.Inst.P. Second edition. London, New York, Toronto: Longmans, Green & Co., 1949. (Pp. x + 255, with 139 figures, including 8 plates.) 12s. 6d. net.

Recent Advances in Radio Receivers. By L. A. Moxon. Cambridge: at the University Press, 1949. (Pp. x + 183, with 91 figures.) 18s. net.

Radio Aerials. By E. B. Moullin, M.A., Sc.D., Fellow of King's College, Cambridge and Professor of Electrical Engineering in the University. International Monographs on Radio. Oxford: at the Clarendon Press, 1949. (Pp. xii + 514, with 243 figures, including 4 plates, and 53 tables.) 50s. net.

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Chapman & Hall, Ltd., 1949. (Pp. viii + 600, with 31 figures and 84 tables.) 48*s*. net.

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The Story of Animal Life. By Maurice Burton, D.Sc., Deputy Keeper, Department of Zoology, British Museum (Natural History). With special articles contributed by Zoologists of various countries. Vol. I : The Framework of Animal Life. Invertebrates. Vol. II : Vertebrates. London : Elsevier Publishing Co., Ltd., 1949. (Vol. I : pp. xii + 381 ; Vol. II : pp. viii + 423 ; with over 1000 illustrations in black and white and colour.) 63s. the set.

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The Theory of Inbreeding. By Ronald A. Fisher, Sc.D., F.R.S., Arthur Balfour Professor of Genetics, University of Cambridge. Edinburgh and London : Oliver & Boyd, 1949. (Pp. viii + 120, with 8 figures and 64 tables.) 10s. 6d. net.

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Multi-Enzyme Systems. By Malcolm Dixon, Ph.D., Sc.D., F.R.S., Reader in Enzyme Biochemistry in the University of Cambridge. Four special lectures given to University College, London, in May 1948. Cambridge : at the University Press, 1949. (Pp. viii + 103.) 7s. 6d. net.

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Vitamins and Hormones, Vol. VII. Edited by Robert S. Harris, Professor of Biochemistry of Nutrition, Massachusetts Institute of Technology, and Kenneth V. Thimann, Professor of Plant Physiology, Harvard University. New York : Academic Press, Inc. ; London : H. K. Lewis & Co., Ltd., 1949. (Pp. xii + 488, with 59 figures and 51 tables.) 58s. 6d. net.

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Bacteriological Technique. A Guide for Medical Laboratory Technicians. By W. W. W. McEwen, A.I.M.L.T., F.R.M.S., Chief Technician, Pathological Laboratory, Neath General Hospital. With a Foreword by Professor Sir Alexander Fleming, F.R.C.P., F.R.C.S., F.R.S. London : J. & A. Churchill, Ltd., 1949. (Pp. viii + 286, with 70 figures, including 4 plates.) 15s. net.

The History of the Biochemical Society, 1911–1949. By R. H. A. Plimmer. Printed for the Society at the University Press, Cambridge, 1949. (Pp. 24.) 2s. 6d. net.

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Psychical Physics. A Scientific Analysis of Dowsing, Radiesthesia and Kindred Divining Phenomena. By S. W. Tromp, Professor of Geology Fouad I University, Cairo. Amsterdam : Elsevier Publishing Co., Inc. London : Cleaver-Hume Press, Ltd., 1949. (Pp. xvi + 534, with 150 figures.) 60s. net.

SCIENCE PROGRESS

THE EVOLUTION OF THE EARTH'S ATMOSPHERE

By SIR HAROLD SPENCER JONES, M.A., Sc.D., F.R.S.

Astronomer Royal

THE composition of the Earth's atmosphere in its lower levels at the present time, according to Paneth, is as follows :

COMPOSITION OF ATMOSPHERE (*after* PANETH)

Gas.	Molecular Weight.	Fraction (Volume) × 10^6.	Amount (cm. S.P.T.).
N_2	28·1	780,900	624,600
O_2	32·0	209,500	167,600
A	39·9	9,300	7,440
CO_2	44·4	300	220
Ne	23·2	18	14
He	4·0	5·2	4·2
CH_4	16·0	2·2	1·7
Kr	83·7	1	0·8
N_2O	44·0	1	0·8
H_2	2·0	0·5	0·4
O_3	48·0	0·4	0·3
Xe	131·3	0·08	0·06
H_2O	18·0	10^2–10^4	10^2–10^4

Except for the dissociation of oxygen, which begins at a height of about 80 km., the composition of dry air must be the same up to heights of 100 km. or more, turbulence and convection currents keeping the atmosphere well mixed. At greater heights gravitational separation of the molecules according to molecular weight will commence, but the height at which complete diffusion equilibrium is attained is not known. Between 100 km. and 300 km. height, oxygen becomes completely, and nitrogen partly, dissociated, but the changes in composition are not likely to be very great. At considerably greater heights diffusion equilibrium will cause hydrogen and helium to become the dominant constituents.

In the outermost region of the atmosphere atomic collisions become infrequent; above a certain critical level the atoms spend most of the time in free flight. Atoms soar up into this region, move freely under the action of gravitation and, for the most part, fall down again into the denser layers without undergoing a collision. Spitzer has estimated the height of this critical level to be somewhere between 500 and 1000 km. The distribution of the atoms in the region above the critical level is close to that in an isothermal gas with temperature equal to that at the critical level, and a state of almost complete diffusion equilibrium is attained. Various arguments suggest that the temperature at the critical level is at least 500° K. and may be as high as 1500° K. The mean free path is so great that particles with sufficient energy are able to escape from the atmosphere. The tendency to escape is greater the lighter the atom, because, in consequence of the equipartition of energy, the lighter the atom the greater the mean velocity.

For an isothermal atmosphere the time of escape (the time in which the density would fall to $1/e$ of its value) for any particular gas is given, according to the calculations of Jeans, by

$$t_1 = \frac{C^3}{2g^2a} e^{3ga/c^2}$$

where C is the root mean-square velocity for the particular gas, a is the radius of the Earth, g the surface gravity.

Spitzer has pointed out that a correcting factor is required to this formula. It is based on the assumption that the atmosphere is in isothermal equilibrium. In the escape region there is isothermal equilibrium corresponding to the temperature at the critical level, but the temperature of the lower atmosphere is much lower than the temperature at the critical level; the density at the lower heights is consequently much greater than the corresponding density in the hypothetical isothermal atmosphere. The actual total atmospheric mass is therefore much greater than the mass of an isothermal atmosphere with the temperature of the critical level. The time of escape is correspondingly much increased. Spitzer has computed the correcting factor and finds a value of about 5×10^6 for hydrogen and helium and somewhat smaller values, depending upon the critical temperature, for other gases. For different assumed values of the temperature at the critical layer he has computed the times of escape for hydrogen, helium, nitrogen, and oxygen, as in the table opposite.

For any appreciable amount of helium to escape during the lifetime of the Earth, the temperature at the critical level must

be about 1500° K.   The temperature could normally have a lower value if it is considerably raised at times when the ultra-violet emission of the Sun is greatly increased, during the occurrence of bright eruptions on the Sun.   A temperature at the critical level of 2000° K. for 2 per cent. of the time and of 500° K. at normal times would be adequate to account for the escape of helium from the Earth.

<div align="center">TIME OF ESCAPE IN YEARS</div>

	500° K.	1000° K.	2000° K.
H . .	$2 \cdot 4 \times 10^7$	$3 \cdot 6 \times 10^4$	$1 \cdot 8 \times 10^3$
He . .	$4 \cdot 2 \times 10^{25}$	$4 \cdot 0 \times 10^{13}$	$2 \cdot 4 \times 10^7$
N . .	10^{92}	10^{45}	$3 \cdot 9 \times 10^{22}$
O . . .	10^{105}	10^{51}	$1 \cdot 0 \times 10^{24}$

The supply of helium is being continually added to by the weathering of the igneous rocks of the Earth's crust, which contain uranium and thorium and, consequently, helium also.   The amount of helium that has been added to the atmosphere during geological times as the result of the weathering of the igneous rocks is many times greater than the amount which it now contains.   There is thus direct observational evidence that helium has been lost from the atmosphere during geological times.   It is not possible, however, to base any conclusions about the temperature of the critical level on this fact, for there is another process by which the escape of helium can be brought about.   It is well known that the night sky is faintly luminous and that in its spectrum the characteristic green auroral lines, as well as the two red lines, are present.   These lines are emitted by oxygen atoms that are in a metastable state.   An atom in such a state has only a slight tendency to unload its energy and may exist for a second or longer before emitting its energy in the form of radiation, whereas an atom, when excited or loaded up with energy, usually unloads it, with the emission of radiation, within a time of about 10^{-8} seconds.   There is a high probability that an atom in the metastable state, just below the critical level, will come into collision with another atom before it can emit its energy.   When a collision occurs, the energy of the metastable atom is converted into kinetic energy, with the result that the atoms rebound with greatly increased speeds.   By collision with a metastable oxygen atom, an atom of helium can acquire a speed of more than 12 km./sec., which is greater than the velocity of escape ; if it rebounds into the region above the critical level it will escape. Hydrogen atoms will acquire a still higher speed, but heavier atoms,

such as those of oxygen and nitrogen, could not by this process acquire sufficient speeds to escape. The loss of hydrogen and helium from the Earth's atmosphere at the present time can be partly accounted for in this way.

Nitrogen, oxygen, and all heavier gases cannot escape to any appreciable extent, on any reasonable hypothesis of the temperature at the critical level, in a period equal to the lifetime of the Earth. It might consequently be supposed that the oxygen and nitrogen in the Earth's atmosphere are the remnants of a primitive atmosphere, from which hydrogen and helium, if initially present, have been lost. The inert rare gases provide information which enables this supposition to be checked ; they form no compounds and it is possible to assign with some accuracy upper limits to the amounts contained in the Earth, which can be compared with their cosmic abundances.

When the metals are considered, it is found that those metals which are most abundant in the Earth are those which are also found to be the most abundant in the Sun ; those which are rare in the Earth—such as lithium, beryllium, scandium, gallium, and indium—are found to be rare also in the Sun. The relative abundances of the different metals in the Earth prove to be in such close agreement with their relative abundances in the Sun that it is not possible to say with certainty that any particular metallic element is relatively more or less abundant in the Earth than in the Sun. When the compositions of the stars are investigated, it is likewise found that there is a close similarity in composition between the Sun and the stars. It may be supposed either that the stars, including the Sun and its family of planets, have all been formed from the same primæval material or that a common process of atom building has taken place throughout the Universe, resulting in the same relative proportions of different atoms in its various parts.

Turning from the metals to the non-metals, there is a general similarity between the compositions of the Sun and of the stars, but this similarity does not extend to the Earth. The cosmic abundance of hydrogen greatly exceeds that of any other element, helium being the next most abundant element. For every 1000 atoms of hydrogen, there are about 100 atoms of helium, while the total number for all the other elements, both metals and non-metals, is only about two. The great preponderance of hydrogen and helium throughout the Universe does not extend to the Earth. It is not surprising that for those two elements there should be such a difference between their cosmic and terrestrial abundances,

for, as we have already seen, it is to be expected that these light gases will, in the course of geological time, have largely escaped from the Earth. What is surprising, however, is to find that there are also very large discordances between the cosmical and terrestrial abundances of all the inert gases, neon, argon, krypton, and xenon.

Data bearing on the terrestrial abundances of the inert gases are provided by Paneth's determinations of the amount of each of these gases in the atmosphere, by Lord Rayleigh's determinations of the neon and argon contents of various rocks, and by the measurements by Cady and Cady of the helium, neon, argon, and the krypton and xenon contents of a number of natural gases. The three lines of investigation give results which are mutually in good agreement. From the combination of all the data a minimum estimate of the rare gas content of the Earth can be obtained by considering the amounts in the atmosphere alone, leaving amounts contained in the rocks entirely out of consideration ; an over-estimate can be obtained on the assumption that the entire mass of the Earth contains the same rare gas content per unit mass as the surface rocks, and by adding to the amount so obtained the rare gas content of the atmosphere. It is convenient, in the consideration of the relative abundances, to use the values relative to silicon, which is a major component of the Earth, and which enables the terrestrial abundances to be related to the cosmic abundances. Harrison Brown has given the following estimates of the maximum and minimum amounts of the rare gases in the Earth, and of their atomic ratios to silicon (based on an estimated silicon content of the Earth as a whole of 8.4×10^{26} gm.) :

MINIMUM AND MAXIMUM ESTIMATES OF TERRESTRIAL AMOUNTS OF RARE GASES

Gas.	Total Weight (gm.).		Atomic Ratio to Silicon (by numbers).	
	Minimum.	Maximum.	Minimum.	Maximum.
Ne	6.7×10^{16}	4.9×10^{17}	1.1×10^{-10}	8.1×10^{-10}
A .	6.6×10^{19}	3.0×10^{20}	5.5×10^{-8}	2.5×10^{-7}
Kr	1.5×10^{16}	1.1×10^{17}	6.0×10^{-12}	4.4×10^{-11}
Xe	1.9×10^{15}	1.4×10^{16}	4.9×10^{-13}	3.6×10^{-12}

The cosmic abundances of different elements have been compiled by Goldschmidt. The data for the rare gases are not very precise, but there are regularities between the abundances and the mass numbers which make it possible to interpolate the abundances of the rare gas isotopes with some precision. In this way the cosmic abundances for the Ne 21, A 36, Kr 83, and Xe 131 isotopes were

derived. Expressed in terms of atoms per 10,000 atoms of silicon the estimated abundances were as follows :

ESTIMATED COSMIC ABUNDANCES OF CERTAIN RARE GAS ISOTOPES

Isotope.	Atoms per 10,000 Si.	Isotope.	Atoms per 10,000 Si.
Ne 21	100	Kr 83	0·1
A 36	1000	Xe 131	0·004

With the aid of data for relative isotopic abundances provided by mass spectrograph measurements, the above data for particular isotopes can be used to give the total abundance. In the case of argon, however, only the isotope 36 was used ; the bulk of the isotope 40 of argon has probably been produced by the decay of the radioactive isotope 40 of potassium ; the isotope 36 of argon is not produced by radioactive decay.

The following abundances of the rare gases relative to silicon were derived by Harrison Brown in this way :

ESTIMATED COSMIC ABUNDANCES OF THE RARE GASES

Gas	Atoms per 10,000 Si.	Gas.	Atoms per 10,000 Si.
Ne	37,000	Kr	0·87
A (36)	1,000	Xe	0·015

The marked discordance between the cosmic abundances of the rare gases relative to silicon and the maximum terrestrial relative abundances given above will be noted. The ratio between the cosmic abundance ratio and the terrestrial abundance ratio is termed the " fractionation factor " by Harrison Brown, denoting the extent to which the rare gases were fractionated from silicon during the process of Earth formation. The maximum and minimum fractionation factors are as follows :

Element.	Atomic Weight.	Fractionation Factor.
Neon . . .	20	$3.10^{10}- 5.10^{9}$
Argon . . .	40	$5.10^{8} -1·5.10^{8}$
Krypton . . .	83	$1·5.10^{7} \quad 2.10^{6}$
Xenon . . .	130	$3.10^{6} - 4.10^{5}$

Thus even in the case of a gas as heavy as xenon, the present terrestrial abundance is less than 0·001 per cent. of its cosmic abundance.

Bearing in mind the range of atomic weights, it follows that, in the process of Earth formation, no appreciable fraction has been retained of any substance which then existed primarily in the gaseous state. The only possible conclusion from the comparison

between the cosmic and terrestrial abundances is that the Earth must have lost its primitive atmosphere almost completely.

The upper and lower limits for the fractionation factors of the inert gases form smooth curves when plotted against atomic weight. It is possible by interpolation to infer the fractionation factors for the principal constituents of the Earth's present atmosphere and, on the basis of the observed cosmic abundances of these constituents relative to silicon, to compare the amount of each that is now contained in the atmosphere with the amount that would be expected in relation to the present amount of the rare gases. The data have been given by Harrison Brown.

The inferred maximum and minimum fractionation factors are as follows :

Water	$1 . 10^{11} - 1 . 10^{10}$
Nitrogen	$3 . 10^9 \quad 6 . 10^8$
Oxygen	$1 \cdot 5 . 10^9 \quad -3 . 10^8$
Carbon dioxide	$2 \cdot 5 . 10^8 \quad -5 . 10^7$.

The cosmic abundance ratio of oxygen to silicon is about 4 [*] If half of the oxygen initially present in the Earth is assumed to have combined with metallic elements and the other half to have combined with hydrogen to form water, the initial ratio of water to silicon would be about 2. The maximum water to silicon ratio at the present time should then be only 2×10^{-10}. But the amount of water on the Earth's surface amounts to 280 kg. per square cm., from which it can be inferred that the actual water to silicon ratio is greater than $2 \cdot 7 \times 10^{-3}$. It follows that there is not less than 10^7 times more water on the Earth's surface than would be expected.

In the case of nitrogen the cosmic abundance ratio to silicon is about $1 \cdot 5$. On the basis of the minimum fractionation factor of 6×10^8, the maximum nitrogen to silicon ratio at the present time should be only $2 \cdot 5 \times 10^{-9}$. In the atmosphere alone there are 755 gm. of nitrogen per sq. cm. of surface. Lord Rayleigh's investigations of the nitrogen content of igneous rocks led him to the conclusion that the total amount of nitrogen occluded in these rocks is about 50 times the total amount in the atmosphere, without allowing for possible nitrogen compounds in the central core. It follows that for the entire earth the ratio of nitrogen to silicon is greater than $4 \cdot 5 \times 10^{-4}$, which is greater by a factor of about 180,000 than that to be expected.

The amount of carbon dioxide in the free state in the atmosphere and dissolved in sea water is about 20 gm. per sq. cm. The " fossil "

[*] More recent data indicate a ratio of about 12, but the argument is substantially unaffected.

carbon dioxide in coal, bitumen, humus, and in the carbonates of sedimentary rocks is, according to Goldschmidt, about 400 times greater than the amount in the atmosphere and the oceans. It follows that the present ratio of carbon to silicon is at least 4×10^{-5}. The cosmic abundances of carbon and of nitrogen are about equal. The minimum fractionation ratio for carbon dioxide is 5×10^7 and, if it is assumed that all carbon was originally in the form of carbon dioxide, the maximum carbon to silicon ratio on the earth should be 3×10^{-8} ; this ratio is likely to be a gross overestimate. The amount at present is some 1300 times greater than this maximum.

For oxygen the minimum fractionation factor is 3.10^6. If half the oxygen in the material from which the earth was formed were free oxygen (which is highly improbable and likely to be a considerable overestimate), the ratio of oxygen gas to silicon should not be greater than 7.10^{-9}. In the atmosphere alone there are 230 gm. of oxygen per sq. cm. of surface. Leaving out of consideration the oxygen fossilised in bituminous deposits and carbonates, the ratio of oxygen gas to silicon at present is greater than 2.4×10^{-6}, which is 340 times greater than the maximum expected amount.

The conclusion from this discussion is that the amounts of the major constituents—water, nitrogen, oxygen, and carbon dioxide—now present in the atmosphere and in the oceans (regarding them as having been condensed from the atmosphere) are far in excess of the amounts that would be expected in relation to the amounts of the rare gases remaining in the atmosphere and to the respective cosmic abundances. These constituents of the earth's present atmosphere cannot be the remnants of its primitive atmosphere. The present atmosphere must be of secondary origin ; these substances, or their constituent elements, must have been retained in chemical combination instead of in a free state, and must have been released as the result of chemical processes subsequent to the loss of the initial atmosphere and the formation of a solid crust. The Earth must have lost its primitive atmosphere almost entirely during the process of earth formation and must subsequently have produced a new atmosphere.

Some inferences about the atmosphere during geological time are possible. Chamberlin has pointed out that unmistakable evidences of glaciation have been found in very old Archæan rocks. Unless the Sun's output of radiation was appreciably less than at present, it seems impossible that glaciation could have occurred at a time when the Earth still had a dense atmosphere, containing much carbon dioxide ; this gas exerts a very strong greenhouse

effect, which increases not only with the amount of carbon dioxide through which the radiation passes, but also with the total pressure of the gaseous atmosphere. The dense envelope of carbon dioxide had therefore most probably been lost before the earliest geological times. During geological times, widespread glaciation and ice ages have alternated with warm periods. It was during these warmer periods that the limestone deposits were formed beneath the oceans from the bodies of small marine organisms and that, in later ages, the coal measures were formed. The large quantities of carbon dioxide required to form these carbonate and carbonaceous deposits must have been supplied to the atmosphere gradually and progressively after the primitive atmosphere had been lost.

Free oxygen must also have been present in considerable amounts in the atmosphere from the earliest geological times, because iron ores in the fully oxidised ferric state are found in many of the oldest Archæan rocks. Furthermore, fossils of animals are found in the earliest water-laid sediments, with an age of about 500 million years ; some of these are of types so similar to some of the present-day forms as to suggest that living conditions in those early times could not have been greatly different from what they are today. Chamberlin has stated that " the early Cambrian trilobites and other forms are so completely organised that zoölogists believe that more than three-quarters of the total evolution of the animal kingdom from the single-cell stage to the highest present types had already taken place before the Cambrian, and of this the rocks have told us next to nothing." He concludes that, throughout geological time, the Earth's atmosphere has contained plenty of oxygen and not too much carbon dioxide, and that the climatic and atmospheric conditions have not changed progressively. There has been a rhythmic alternation of conditions, corresponding to the succession of geological periods.

The beginning of a typical geological period follows the crumpling of the crust and extensive mountain formation ; the continental areas stand high and there are extremes of climate. Much rock surface is exposed to glaciation. A portion of the atmospheric carbon dioxide then dissolves in the cooler ocean waters : its greenhouse effect is reduced, and glaciation may occur. The high lands are in the course of time gradually worn down by erosion, solid material is deposited beneath the oceans, forming sedimentary deposits, the ocean level rises, and the lower continental areas are flooded. Climates become less extreme ; they are relatively uniform and warm. This phase is characterised by the formation of limestone by lime-secreting organisms, carbon dioxide being liberated

in the process, some of which is given off to the atmosphere. This in turn results in increased carbonisation of calcium-bearing igneous rocks on land, carbon dioxide being taken from the atmosphere. The growth of the sedimentary deposits eventually upsets the crustal equilibrium and a new period of mountain building results, the cycle beginning again. The geological cycle is more complex than suggested here and is less uniform. The essential point is that it has involved a balancing of opposing factors, with sometimes one, sometimes the other, prevailing. The composition of the atmosphere has most probably fluctuated with these alternations in conditions, but it is not to be supposed that the changes have been considerable. But if, as we conclude, the Earth has formed a new atmosphere since the loss of its primitive atmosphere, where have the oxygen, nitrogen, carbon dioxide, and water vapour, which form its principal constituents and the oceans, come from ? Chamberlin considers that they have been produced by extensive volcanic action. He points out that the total volume of the lava flows which have reached the Earth's surface, through volcanic and fissure eruptions, in the course of geological time is enormous, and that the intrusions which have solidified not far below the surface are still greater. The extruded magmas have brought with them from the depths great quantities of dissolved gases, many of which are liberated as the pressure is reduced, though a portion is retained on solidification. By far the most abundant of the volcanic gases is water vapour, next in abundance being carbon dioxide.

There is no means of estimating how much water vapour has been discharged into the atmosphere by volcanic action in the course of geological time. But in the case of carbon dioxide Goldschmidt has shown, as already mentioned, that the sedimentary rocks and coal measures contain about 400 times the amount of carbon dioxide now in the atmosphere. It is supposed that, as the carbon dioxide was progressively added to the atmosphere by volcanic action, some of it dissolved in the oceans, which in turn lost it through the formation of the limestone sedimentary deposits.

The problem of atmospheric oxygen is more difficult. Volcanoes do not emit free oxygen. Any free oxygen that might be present in the volcanic gases would at once be used up in oxidising the ferrous iron in the hot lava ; in fact, some of the steam in the gases is broken up in the presence of the hot ferrous oxide, the oxygen being used in the formation of ferric oxide and free hydrogen being emitted with the volcanic gases. The uncombined oxygen in the air cannot have been produced by volcanic action. It is a matter for some surprise that the Earth's atmosphere contains

so great a proportion of free oxygen because, oxygen being an element that is chemically very active, processes are in continual operation which are depleting the store of oxygen in the atmosphere. One of the principal processes is the weathering of the igneous rocks to form sedimentary deposits. The iron in the igneous rocks is not completely oxidised, as the general greyish hues of these rocks indicates. In the process of weathering, much of the ferrous oxide is oxidised into ferric oxide, giving the brown or red tints of the weathered deposits. The amount of oxygen that has been withdrawn in this way from the atmosphere during geological time and permanently buried is very considerable. Goldschmidt has estimated that it is at least as much, and possibly twice as much, as all that now remains in the atmosphere. It is clear that some process must be at work which replenishes the oxygen in the atmosphere.

There is little doubt that the vegetation over the Earth's surface provides the means for this replenishment, through the process of photosynthesis. Plants absorb carbon dioxide from the atmosphere and use the energy from sunlight to decompose it, the chlorophyll in the plant cells acting as the energy transformer ; the carbon is used to build up the plant cells and the oxygen is returned to the atmosphere. When, conversely, vegetable matter and other organic materials decay, oxygen is absorbed and carbon dioxide is liberated. This carbon dioxide is again available for building up plant cells. Whenever organic matter is buried, as in coal measures and oil deposits, so that it cannot be oxidised, there is a net gain of oxygen to the atmosphere. If the present abundance of oxygen has been provided in this way, there should be enough organic matter buried in the sedimentary rocks to use up all the free oxygen in the atmosphere, if it could be uncovered and burned. Goldschmidt has estimated the " fossil " oxygen, under two different assumptions, to amount to 0·256 and 0·544 kg. per cm.^{2} of the Earth's surface ; the present amount of oxygen in the atmosphere is 0·230 kg. per cm.^{2} of the Earth's surface and the amount dissolved in the sea is 0·002 kg. per cm.^{2} If the total amount of oxygen, both free in the atmosphere and fossilised in the rocks, had been formed from carbon dioxide through photosynthesis by plants, the amount of carbon required per sq. cm. of the Earth's surface is, on the two assumptions, 0·183 and 0·291 kg. The amount of carbon in the sedimentary rocks and bituminous deposits is more than adequate for this requirement. The geological evidence is therefore consistent with the hypothesis that the present oxygen content of the atmosphere has been produced by photosynthesis in plants.

The atmosphere of Venus provides a striking contrast to that of the Earth. It contains a considerable amount of carbon dioxide, estimated to be equivalent to a thickness of two miles at standard pressure and temperature, but observations have failed to detect either oxygen or water vapour, though they are sufficiently sensitive to detect amounts of only one-thousandth of the amounts in the Earth's atmosphere. It is certain that Venus is an arid world ; its surface is largely desert and the haziness of its atmosphere is due to dust, which is swirled up by the vigorous atmospheric circulation, intensified because of the high temperature resulting from the greenhouse effect of the carbon dioxide. Under such conditions, it is not to be expected that there could be any vegetation on Venus ; there are no plants to produce oxygen through the medium of photosynthesis and the absence of oxygen from its atmosphere is not, therefore, surprising.

Lord Rayleigh showed that the nitrogen content of igneous rocks is remarkably constant in amount for all types of such rocks—from ultrabasic to acidic—and he estimated that the total amount of occluded nitrogen was about fifty times the amount in the atmosphere. The volcanic magmas must bring out some nitrogen (partly, possibly, in combination with hydrogen as ammonia) into the atmosphere, though the amount is much less than the amount of carbon dioxide. Any ammonia would be broken up by photochemical action of sunlight. A portion of this nitrogen added to the atmosphere by volcanic action will be lost from it to nitrates and other nitrogenous deposits, but it is estimated that the amount so lost will be only about 10 per cent. The bulk of the nitrogen, a relatively inert gas, has remained in the atmosphere, in contrast to the carbon dioxide and oxygen, which have been lost to a considerable extent from the atmosphere ; the amount in the atmosphere has progressively increased, so that nitrogen is now its chief constituent.

The gases emitted from volcanoes contain also sulphurous gases, hydrochloric and hydrofluoric acids, etc. ; these are soon removed by precipitation, and do not therefore increase in total amount.

It seems therefore that a pretty clear picture of the evolution of the Earth's atmosphere can be drawn. While the Earth was still at a high temperature, in its extreme infancy, it rapidly lost practically the whole of its primitive gaseous atmosphere. No appreciable fraction of a gas as heavy as xenon (atomic weight 130) was even retained. The small amounts of the rare gases found in the atmosphere, in natural gases, and occluded in rocks—which, because of their inertness, have not entered into chemical combina-

tion with other elements—represent the residuum of the primitive atmosphere.   Practically the whole of the nitrogen, oxygen, carbon dioxide, and water vapour were naturally lost along with the inert gases and any other gaseous constituents.   The present atmosphere is therefore of secondary origin, and has been formed by chemical processes.   Volcanic action in the course of geological time has been responsible for the production of the present atmosphere ; water vapour, carbon dioxide, and nitrogen have been produced directly by volcanic action, but free oxygen has been formed from carbon dioxide through the medium of plant action.   There is considerable evidence that the present atmosphere is of considerable antiquity and that since early geological times, though the composition has fluctuated somewhat, the changes have not been very great.

LIFE ON SANDY SHORES *

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THE shore is broadly divisible into the three major environments of rock, sand and mud, although with all manner of intergradations between these. The inhabitants of rocky shores must, above all else, have ability to withstand the mechanical violence of wave action, to counter the effects of desiccation and of extremes of temperature, possibly also of salinity. This they accomplish by a variety of means frequently involving purely physiological, as well as or instead of morphological, adaptations.

On sandy, and also muddy, shores the inhabitants survive by evading these dangers and this they accomplish by burrowing. The receding tide exposes an apparently barren stretch of sand, all the animals having sought safety by burrowing. This habit, however, demands structural adaptations of such complexity that relatively few species—in comparison with the very great numbers that occur on rocky shores—have succeeded in colonising sand or mud. But the successful species are frequently enormously abundant.

Sand is an *unstable* medium, in this respect differing from mud which is deposited in more protected areas, at the end of deep bays or at the mouths of estuaries. Mud dwellers frequently inhabit permanent burrows, but on an exposed beach such burrows could not be maintained. Animals living in sand must be able to reburrow immediately if exposed and then to re-establish contact with the water above as soon as this is possible. Only the most active of burrowers, fully adapted for life in a most unstable medium, can exist on an exposed beach. In more protected areas, where the sand becomes mixed with increasing amounts of organic matter, other and less active burrowers occur. In real mud new problems present themselves, the finer particles tend to clog feeding and respiratory mechanisms, while the greater admixture of organic matter may result in lowered oxygen tension. Sand-dwelling animals are not

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* This article represents some expansion of the Kennedy-Orton Lecture delivered at the University College of North Wales, Bangor, on February 13, 1950.

adapted for life under such conditions and give place to a character-
istic mud fauna.

Sand is composed of fine particles of hard rock, around Great
Britain mainly of quartz grains with a coating of iron oxide and
varying admixtures of calcareous particles (Bruce, 1928a). These
particles, derived from material brought down by rivers or from
coastal erosion, tend to be carried alongshore and to be deposited
where water movements lessen. Thus bar beaches are formed a little
distance offshore, crescent beaches at the heads of wide bays, and
pocket beaches within smaller indentations along rocky coasts.
Problems of beach formation and maintenance have been the subject
of recent discussion by Shepard (1948).

In relation to animal life two characteristics of beaches are of
particular significance, namely stability and gradient. Beaches
retain their form only so long as water movements are constant and
so they vary in relation to seasons, to the tidal cycle and to individual
storms. The gradient of the beach (although this also fluctuates in
relation to tides and storms) is a function of the size of the con-
stituent particles as shown in Table I.

TABLE I

(*from* Shepard, 1948)

Beach Type.	Median Diameters in mm.	Depositional Slope.
Very fine sand.	0·016	
Fine sand	0·12	
		2°
Medium sand	0·25	
		4°
Coarse sand	0·5	
		8°
Gravel	2·0	
		12°
Cobble	64·0	
		20°
Boulder	256·0	

Thus the finer the particles the more gentle the slope, but there is
a tendency for large grains of sand to be carried above high-water
level, so that intertidal sands come to consist of medium and small
grains with a gentle gradient.

Above all else life in sand is affected by the amount of water
which is retained when the tide retreats or which can be raised from
lower levels by capillarity. Both, as emphasised by Bruce (1928a),
are associated with grade. The former is determined by the total
surface area of the sand grains round which a film of water is retained

which, running from one grain to another, largely fills the pores or interstitial spaces between these. This film also protects the sand grains and acts as a cushion between them. Capillarity, in its turn, depends upon the width of these spaces. As shown in Table II, if sand be separated by sieving into various grades the greatest water content, i.e. interstitial space, is found in the sand of finest grade. But natural, ungraded sand has a very low water content because of the reduction of interstitial space, smaller grains occupying the spaces between larger ones.

TABLE II

(*from* BRUCE, 1928a)

WATER CONTENT, AT SATURATION, OF DIFFERENT GRADES OF SAND

Grade Meshes per Inch.	Diameter Sand Grains in mm.	Vols Water present in 100 vols. Wet Sand.
Greater than 30 . . .	- .0·51	35·8
30– 60	0·53 0 28	39·0
60– 90	0·27 0·16	42·0
90–120	0·15 0·12	42·2
120–150	0·11–0·09	44·7
Passing 150	- . 0·09	43 4
Ungraded, natural sample		20·0

Since capillarity depends on the actual width of the channels between the grains and not on the total volume of the spaces represented by these, capillary rise is greater in fine sand of 120–150 mesh than in coarser grades. But here again the finest capillary channels occur, for the reason mentioned above, in natural ungraded sand in which, as shown in Fig. 1, the greatest capillary rise occurs (Bruce, 1928a).

Water-saturated sands thus achieve a measure of stability with their grains separated from one another and yet held together by the bounding films of water. Such wet sands have the properties either of dilatancy or of thixotropy, the nature of which and their signi-

FIG. 1.—Effect of grade upon capillary rise of sea water through sands.

A, ungraded sand; B, grains 0 11–0 09 mm. diameter; C, 0·15–0 12 mm.; D, 0·27–0·16 mm.

(*After* BRUCE, 1928a.)

ficance to certain sand-dwelling animals have recently been studied by Chapman and Newell (1947) and Chapman (1949). Dilatancy, the effects of which are seen when sand is whitened under pressure, as of a foot, is defined as a condition when increased resistance is opposed to increased rate of sheer. The close packing of the sand grains is disturbed by the pressure and the enlarged interstices between them can no longer be filled by the available water. But with an increase in the content of water from about 22 to 25 per cent. (although there may be other influencing factors) dilatancy gives place to thixotropy. The result of pressure, by agitation of the sand, is now to bring about precisely the opposite result, namely a decreased instead of an increased resistance. Chapman and Newell found that in certain sands agitation led to a reduction of resistance to penetration from 412 to 41 grams per square centimetre. Thus, owing to this property of thixotropy, resistance dropped to one-tenth. The original resistance was regained in thirty seconds. The significance of these factors, particularly of thixotropy, in relation especially to the life and distribution of the lugworm, *Arenicola marina*, will later call for comment.

Changes both of temperature and of salinity experienced at the surface of sands when the tide is out diminish quickly with depth. Animals have only to burrow to maximum depths of about 1 ft. to escape change in salinity even though fresh water is running over the surface (Bruce, 1928a ; Reid, 1930, 1932). Similarly the surface of the beach experiences wide and often most abrupt changes in temperature as the tide rises and falls. Although evaporation may check excessive rise of summer temperatures, extremes remain great enough to demand for survival considerable powers of physiological adaptation. Such powers, essential for survival on exposed rocky shores, remain unnecessary to sand-dwellers capable of burrowing to a depth of some 8 in. (Bruce, 1928a). At appropriate depths constant conditions of both salinity and temperature are usually reached by all animals capable of burrowing so far.[*] Furthermore, the excretion of carbon dioxide by these buried animals has little effect on the pH of the interstitial water owing to the enormous excess base due to calcareous matter in the sands (Bruce, 1928b).

The grade of sand is of no great moment to the inhabitants except to those animals which swallow sand and may be inconvenienced by large particles. More important is the increasing admixture of organic matter in still areas where fine detritus, derived in the main

[*] Abnormally high temperatures in the summer of 1933 caused great mortality of *Cardium edule* and *Arenicola marina* in Morecambe Bay (Orton, 1933, 1934).

from the breakdown of seaweeds, is deposited. While this does represent a source of food to various sand-dwelling animals, it may also be responsible for underlying layers of black sand, which smell strongly of sulphuretted hydrogen when disturbed. Fine particles of organic matter clog the interstitial spaces and so prevent circulation of water and of oxygen. These spaces are always reduced in these sheltered areas, where sand grains are finer and begin to merge into mud. Under these anaerobic conditions ferrous sulphide, which causes the blackening, is formed by bacterial action. Unless animals have direct access to pure water above, life within sand of this type is impossible. Broadly speaking, where layers of black sand occur there is greater stability and greater supplies of edible detritus, but a dangerous lack of oxygen.

Before discussion of the macroscopical burrowing fauna of sand, brief mention must be made of the interstitial fauna—flora also, because diatoms are present—found in the film of water around
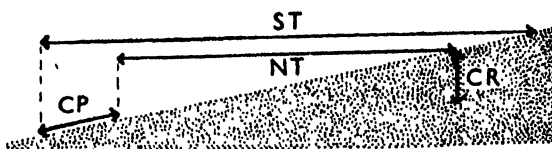
FIG. 2.—Diagram showing vertical and horizontal movements through and over sand by *Convoluta roscoffensis* (CR) and *C. paradoxa* (CP) respectively. NT, ST, range of neap and spring tides.

and between the grains. Protozoa, flatworms, nematodes, rotifers and copepods are among the animals that insinuate themselves between the sand grains. The vertical migrations of the turbellarian *Convoluta roscoffensis*, which contains green symbiotic algæ, must take place within the interstitial spaces. The animals live in sand at the upper limit of lowest high water of neap tides and always in a drainage area, *i.e.* where there is maximum exposure to light without danger of desiccation. Positive phototaxis causes migration to the surface (so occurring only by day), while positive geotaxis causes downward movement when the sand begins to vibrate with the returning tide (Gamble and Keeble, 1904). The allied *C. paradoxa*, which contains brown algal cells, lives on weed about low water mark and migrates horizontally with the spring and neap tides and, for the same reasons as *C. roscoffensis*, migrates vertically (Keeble, 1908). The habits of the two species are contrasted in Fig. 2.

But the copepods are much the most specialised members of this interstitial fauna. As shown originally by Wilson, C. B. (1932, 1935), and later by others, notably Nicholls (1935), interstitial copepods,

though belonging to various families, are all minute and slender, with apparently well developed tactile organs and with special burrowing setæ. All are very feeble swimmers, but are continuously wriggling, so that it is almost impossible to examine them in life. Their powers of locomotion, however, are so limited that, to quote Nicholls (1935), the different species " show an almost specific distribution from low water to the highest part of the beach." There is also a " specific vertical distribution, some species being restricted to the top two or three centimetres of sand while others may be found only below 3 cm., at least during the period of tidal exposure."

The larger animals, with which we are here primarily concerned, burrow by displacing the sand grains, and some of the means used to this important end may very briefly be reviewed. In all the capacity for speedy re-entry after exposure, in some instances voluntary but more often involuntary, is of supreme importance. Broadly stated, burrowing can be carried out by movements of the entire body, as in annelid worms to be mentioned later, or by the action of particular organs, but the entire body is usually modified to some extent.

Unlike the mud-burrowing Crustacea, those that live in sand, whether amphipods or decapods, do not remain permanently within this. Decapods, such as the common shrimp, *Crangon vulgaris*, and the ghost crab, *Corystes cassivelaunus*, appear to burrow by day to emerge for feeding at night. Both sink directly downward when placed on sand. Species of amphipods, notably of the three genera *Bathyporeia*, *Urothoë* and *Haustorius*, would seem, as described later, to emerge only in connection with reproduction. Species of *Bathyporeia* use the second gnathopods and first two pairs of peræopods in burrowing, aided by the two pairs of uropods, but in the other two more specialised genera the animals may be said to swim into the sand, employing essentially the same mechanisms as in swimming.

Sand-burrowing echinoderms show an interesting diversity of method. The starfish, *Astropecten*, sinks down immediately under sand by the action of the pointed, instead of the usual sucker-shaped, tube-feet. The flattened body must assist horizontal movement when it is buried. Heart-urchins, species of *Echinocardium* and allied genera, burrow by the action of their spines. The body has acquired a secondary bilateral symmetry, but it remains doubtful whether they move about much under the surface; more probably they regain the surface at night and then move to another area before sinking very quickly downward into the sand.

The muscular foot of the molluscs, capable of being extruded and then terminally dilated with blood, the animal being drawn forward

by contractions of the pedal muscles, represents an ideal organ for burrowing into a soft substratum. Gastropod burrowers are not numerous and are characterised by the relatively enormous foot of *Natica* and allied genera such as *Polinices*, together with *Olivella* and *Oliva* (see Pearse, Humm and Wharton, 1942) of the coasts of temperate North Africa, and many genera found within the sands of tropical shores. But the bivalve molluscs are probably the most numerous and are certainly economically the most important of sand-dwelling animals. While the majority burrow diagonally into the sand, the most beautifully adapted of them all, the razor-shells, *Ensis* and *Solen*, burrow vertically. To this end both the form of the body and the cylindrical shell and also the shape and mode of action of the foot are adapted (Fraenkel, 1927).

It is illuminating to compare the habits of these razor-shells, specialised for life within the unstable medium of sand, with those of the jack-knife clam, *Tagelus*, of American coasts. This has a similarly elongated shell and also lives vertically, but in the mud or muddy sand of relatively quiet areas. Formerly classified with the Solenacea, *Tagelus* is now incorporated within the Tellinacea (see Yonge, 1949), the resemblance to the razor-shells being due to convergence. The latter move up and down in the sand, coming very near to the surface for feeding and respiration, because the siphons are very short, but being able quickly to burrow downward if disturbed. *Tagelus*, in the more stable medium of mud, inhabits a permanent vertical burrow in which it can move up and down, using the foot like a piston rather than as a mushroom anchor. The separated siphons (typical of the Tellinacea) are much longer than those of the Solenacea and reach the surface by way of separate and permanent channels through the mud. The major differences between these bivalves, superficially so alike but exhibiting so well the fundamental differences between the habits of sand and mud-dwellers, are indicated in Fig. 3.

Fig. 3 – Comparison between vertical movements of (A) *Solen* in unstable medium of sand and (B) *Tagelus* in mud where a permanent burrow is constructed

Sand-burrowers must utilise one of three sources of food, namely plankton, detritus or the bodies of other animals. Their feeding mechanisms and habits of life are modified accordingly. On an exposed beach the great bulk of the population collect suspended

matter, primarily phytoplankton, from the sea when the tide is in. All suspension-feeding bivalves, *e.g.* shallow-burrowers like species of *Cardium* and *Venus* and deep-burrowers such as species of *Ensis* and *Lutraria*, collect food by means of their complexly ciliated gills and palps. So, but with setous mechanisms, do the mole-crabs, *Emerita talpoida* of the Atlantic, and *E. analoga* of the Pacific, coast of North America. These are truly creatures of the surf, being confined to exposed and typically steeply sloping beaches, and being adapted, as are few other sand-dwellers, for life within the zone of continuous water movements. They burrow rapidly by means of the first four pairs of periopods and the uropods, but only into really wet sand (see description and figures in Pearse, Humm and Wharton, 1942). Plankton is strained by the modified first antennae. Feeding takes
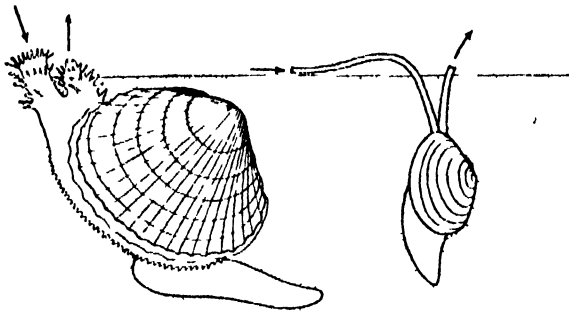
Fɪɢ. 4.—Comparisons between suspension-feeding bivalve, *Cardium edule* (*left*) and deposit-feeding bivalve, *Tellina tenuis* (*right*).

(*From* Yonge)

place when the water of an exhausted wave rushes down the beach, the feathered antennae being later wiped by passage between the mouth parts. According to MacGinitie and MacGinitie (1949), *E. analoga* moves to and fro with the tides, but the animal can feed in still water by sweeping and twisting the antennae. In *E. talpoida*, however, feeding is apparently only possible in moving water, but is then so efficient that even bacteria are collected by the antennae (Zobell and Feltham, 1938).

In more sheltered areas the accumulation of detritus, partly organic in origin, provides an additional source of food. While plankton feeders are still found they are accompanied by detritus feeders. This is the characteristic habitat of the deposit-feeding bivalves, members of the Tellinacea, *e.g.* species of *Tellina*, *Macoma*, *Scrobicularia* and *Tagelus*. As shown in Fig. 4, the siphons are

typically long and always separate, the inhalant siphon being thus enabled to grope freely over the surface and draw, indeed almost suck, in the fine deposits of organic matter that accumulate on the surface in the typically sheltered conditions where they live. There are a variety of correlated adaptations in the musculature, in the organs in the mantle cavity and in the stomach (Yonge, 1949).

This is the habitat of a variety of annelid worms all of which feed on organic matter within the sand, a process which, since it involves swallowing very great amounts of sand, is continued when the tide is out. Species of *Ophelia* and *Thoracophelia*, to be discussed later, provide instances of such worms, but the best and most thoroughly studied example is the lugworm, *Arenicola marina*. The worms, which push their way through rather than swallow the sand (Wells, 1944, 1947), do so by combined action of the pharynx and the body, operated by muscular contraction and hydrostatic pressure and aided by the reduced spines which grip the walls of the burrow. Initial penetration of the surface may be aided by thixotropy, as suggested by Chapman and Newell (1947), or may be due to a purely digging action of the protruded buccal mass, armed with teeth, and followed by the extrusion of the bulbous pharynx (Wells, 1948). The form of the burrow, most typically U-shaped, has been admirably described by Wells (1945) and is shown in Fig. 5. The sand in the head-shaft, which is drawn down from the surface and so is rich in organic detritus, is swallowed and also " worked " by the pharynx so that water is drawn through it. The distribution of lugworms on flats at Whitstable has been correlated by Chapman (1949) with the retention of water due to underlying clay. It is suggested that only where water is so retained can the sand in the head-shaft be " worked " and so the conditions be provided which are essential for feeding and respiration when the tide is out.

FIG. 5.— Diagrammatic section of burrow of *Arenicola marina*, worm *in situ*, surface sand shown white, dark under-layers stippled, plain arrows denote direction of water currents created by worm, broken arrows movement of surface sand down head shaft where " worked " by worm.

(*From* YONGE, *after* WELLS)

Within its burrow the lugworm is in a constant environment, to such an extent that movements both of irrigation and of feeding

appear to be initiated within the animal. Van Dam (1938) described the intermittent periods of respiratory activity, when waves of peristaltic contraction pass along the body in both directions, and Wells (1949a, 1949b) has analysed these and shown their relation to defecation, when the worms move back in the burrow and the typical castings are produced. The latter author finds evidence of the presence of a pacemaker for these irrigation cycles within the ventral nerve cord. Feeding is similarly cyclical, although bursts of activity are more frequent, and here Wells (1937a, 1949b) regards the nerve net in the wall of the œsophagus as the site of the spontaneously active " clock."

From the latter consideration we can pass immediately to carnivorous sand-dwellers, because in the annelid *Glycera* the extrusion of the large and heavily armoured proboscis would appear to be controlled by impulses coming directly from the central nervous system, due in turn to excitation from the receptors (Wells, 1937b). These carnivorous worms are more active but less numerous than the detritus feeders. Other carnivores are the starfish, *Astropecten*, and gastropods, such as *Natica* and allied genera, which bore into the shells, usually of bivalves, by means of an acid-producing gland on the proboscis. Most of the larger sand-dwelling Crustacea, the British *Corystes* and *Crangon*, and the beach crabs of the tropics, such as *Ocypoda*, are scavengers, but the species of *Lysiosquilla*, found also most typically within the tropics, live in very deep burrows and, like all Stomatopoda, are predaceous carnivores.

But all of these animals are few in numbers compared with the plankton and detritus feeders. *Cardium edule*, an example of the former, exists in populations of some 462 millions within a single cockle bed of 320 acres in south Wales (Wright, 1926). The deposit-feeding *Tellina tenuis* has been collected in densities of up to 8000 in a square metre (Stephen, 1928).

The problems of respiration raised by life within sand are not serious except possibly where, in still water, the presence of decaying organic matter leads to lack of oxygen. Both bivalve and gastropod molluscs draw in water from above the surface through an inhalant siphon, the ghost-crab, *Corystes*, by means of the elongated second antennæ which, with the aid of hairs, form a tube to the surface. The presence of hæmoglobin in the blood of *Arenicola* is clearly connected with the need for a reserve of oxygen.

Horizontal zonation on the shore, so obvious in both the flora and fauna of rocky areas, is not so apparent in sand. But it is just as well developed, the different sand-dwelling species varying considerably in their powers of survival by burrowing while the tide is out.

The problem has been well studied in species of the small annelid, *Ophelia*. *O. cluthensis*, an animal between 1 and 2 cm. long, occurs at Kames Bay, Millport, in a restricted zone in the upper third of the beach (Fig. 6) just below high water of neap tides (Brown, 1938). It lives at a depth of some 2 in. below the surface and in densities, in this region, of up to 273 per square metre. *O. bicornis*, some three times as long, is described by Holme (1949) as occurring at Exmouth in loose clean sand about half tide level where it is uncovered by every tide. The maximum density is the same as for *O. cluthensis*. These animals feed on organic matter within the sand. Brown could find no explanation of the restricted horizontal zonation of *O. cluthensis*, but Holme is emphatic that, at any rate for *O. bicornis*, this is to be found in drainage of the sand. His evidence he finds in the distribution of this worm along traverses he studied at Exmouth.

Fig. 6.—Zonation in sand of Kames Bay, Millport.

1–4, zones of horizontal distribution and relative abundance of *Bathyporeia pilosa*, *B. pelagica*, *B. elegans*, *B. guilliamsoniana* (from WATKIN, 1939b); O–O, area (shaded) occupied by *Ophelia cluthensis* (from BROWN, 1938). Dotted line, average low tide level; broken line, mean level of low water spring tides.

Significant additional information comes from work on *Thoracophelia mucronata*, intermediate in size between the two species of *Ophelia*, to which it is closely related. This worm is very common along sandy shores on the Pacific coast of North America from Vancouver south to San Diego and occupies a well-defined zone, varying from 10 to 30 ft. wide according to the slope and other characteristics of the beach (Fox, Crane and McConnaughley, 1948; McConnaughley and Fox, 1949). The worms move vertically within the sand, ascending into the superficial 2 or 3 in. when the tide is out, but descending to depths of a foot or more when the sea returns. They also move about, presumably for feeding, when near the surface. As it becomes less saturated this sand falls in, so that in time the entire area occupied by *T. mucronata* is indicated by a pitting of the surface.

Populations are enormous, that estimated on a mile of beach near San Diego being 158 millions, with a total weight of some 7 tons. The colonies are restricted, it is stated, on the upper side by the depth to which the sand dries between tides and on the lower side by the zone where the sand remains always saturated. One may here assume that feeding is possible only in this intermediate zone between

saturation and dryness occupied by the worms ; it seems doubtful whether they can feed when living at some depth while the tide is in. As in *Ophelia*, sand is swallowed and the animal obtains its nutrition from the colloidal organic matter which is adsorbed on to the sand grains. Since each worm swallows some 24 per cent. of its own weight per hour, it is calculated that 100 grams of worms must ingest some 210 kg. of sand annually. The organic matter is estimated to amount to no more than 1 per cent. of this, representing in all some 2000 grams of food. A colony of worms in a mile-length strip of beach, 10 ft. wide and 1 ft. thick, with an average population of some 300 worms per square foot, would thus pass some 14,600 tons of sand annually through their bodies (McConnaughley and Fox, 1949).

There is a well-marked horizontal boundary between the distribution of the deposit-feeding bivalves *Tellina tenuis* and *T. fabula*, studied by Stephen (1928) at Millport. The former is intertidal, ranging from a little below high-water mark of neap tides to depths of some 4 fathoms, with maximum concentration at mean level of low water of spring tides. *T. fabula* is sub-littoral, with greatest abundance at depths of 4–6 fathoms, and is rarely found on the shore.

Other instances of zonation are provided by the intertidal sand-dwelling amphipods, notably species of *Bathyporeia* (Watkin, 1939a, 1939b). Again Kames Bay, Millport, provides the site of study and, as shown in Fig. 6, there occur in order down the shore : *B. pilosa* which is restricted to a zone above the high level of neap tides, *B. pelagia* which is mid-tidal in distribution, and *B. elegans* and *B. guilliamsoniana* which both occur low on the shore and extend below low water of spring tides. Watkin found that this zonation was even maintained in tow-nettings he made by night over the shore at high tide. About every two weeks, around the times of full and new moon, these animals swim up from the sand. This pelagic phase is connected with reproduction ; the eggs take about fifteen days to develop in the brood pouch, so that periodic emergence into the water above permits of both liberation of the young and fertilisation of the next brood. The whole process must be quickly completed or the horizontal zonation could not be so well maintained. *B. pilosa* breeds throughout the year and so is always in the night plankton around full and new moons, but *B. pelagia* is found there only in spring and summer.

There can be no difficulty in maintaining a population within its particular zone where, as in these isopods, the young emerge at a stage when they are able immediately to burrow. Moreover, in *Arenicola marina*, as recently shown by Newell (1948), reproduction

is related to habit and habitat. Spawning occurs only during the two weeks between the new and full moon spring tides in the second half of October. Both eggs and sperm are discharged from the burrows at the time of extreme low water and so spread over the surface of the sand where fertilisation takes place. The modified trochophore larvæ which develop are demersal and apparently grow within the protection of the *Fucus* zone during the winter and spring.

But where the larvæ are pelagic the manner in which settlement within the zone occupied by the adult is ensured is a problem of major interest. In this connection the work of Wilson, D. P. (1948*a*, 1948*b*) on *Ophelia bicornis* is particularly illuminating. Even in the later stage trochophore larvæ there is a tendency to adhere to solid objects, such as sand grains, by the aid of secretions from the four anal papillæ and the parapodial lobes. Wilson regards this as an adaptive aid to settlement on sand banks which are swept by strong currents. Next comes the question of metamorphosis, for which the larvæ are ready when the first pair of bristles protrudes on the third setiger. But his experiments revealed that the larvæ change to adult form most readily in sand from the natural habitat and with difficulty or not at all in sands from other sources. The particular properties of the natural sand appeared to consist of the smooth and very uniform rounded grains of quartz of which it is composed ; sands composed of smaller and more angular grains were much less favourable to settlement and metamorphosis of the larvæ of *O. bicornis*. Wilson is of the opinion that the sizes and shapes of the interstices between the grains rather than the nature of the grains themselves may, through perception by the tactile sense, be the major stimulus to metamorphosis. The chances of finding the limited zone suitable for adult life are materially increased by the latent period of up to several weeks during which the larvæ, carried to and fro in the water, are able to metamorphose and take to adult life on the bottom should the suitable sandy substratum be encountered. Failing this the larvæ may not change or may do so in some inadequate manner.

Perhaps the most remarkable instances of adaptation to life in—or more accurately on—sand are found in the corals. Here early life is spent attached to a rocky substratum and later life free upon sand. The mushroom corals of the Indo-Pacific, species of the genus *Fungia* and related genera, settle as larval planulæ on to rock and there form a small coral, the free end of which expands and in due course becomes detached as a rounded disc. The original stalk proceeds to form a succession of such individuals. These are carried by water movements to protected areas, typically in the lee of reefs or in the shelter of ramparts of coral fragments, to places, that is,

where sand accumulates. Here these free corals settle, feed and grow. They are able to overcome the major problems of their existence by uncovering themselves after they have been buried under sand (Marshall and Orr, 1931) or righting themselves after they have been turned over by heavy seas (Abe, 1939). A similar " righting reaction " occurs in the sand dollars (*e.g. Echinarachnius*, Parker, 1927), also disc-shaped and at the mercy of storms. A species of a widely different family of corals, the meandrine or brain coral, *Mæandra areolata*, occupies a precisely similar niche in the ecology of Atlantic coral reefs. But here, after a period of growth attached to rock, the base, from which the tissues retreat, becomes eroded and finally breaks through, liberating the coral, but leaving no stump capable of forming other individuals. Again the small free coral is carried by water currents to similar sandy areas, on the surface of which it lives and grows to some size and with the same capacity for uncovering itself when buried (Yonge, 1935). This process involves, as in *Fungia*, the raising of the tissues well clear of the skeleton, as a result of intake of water, but without expansion of the tentacles. The cleansing cilia, fully exposed, are largely responsible for the uncovering of the buried

FIG. 7. Life history of sand dwelling corals, A, fungids where a succession of free individuals is produced by one attached individual ; B, *Mæandra areolata* where young individual breaks free from attachment.

R, rock , S, sand Continuous arrows indicate planula stage in surface waters , broken arrows carriage of freed individuals along bottom from rock to sand

corals. In both types of coral the free adults produce planulæ which are planktonic but must settle on a hard surface (possibly there is some such latent period as described by Wilson for *Ophelia*). The resultant coral may give rise to many free individuals (fungids) or to one (*M. areolata*). These, while still very small, are carried by water movements along the bottom to the area of sand deposition and so to the habitat of the adult. The course of these unusual life histories is indicated diagrammatically in Fig. 7.

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PLATE 1

FIG. 1. -Shells of *Carbonicola* in mudstone, Coal Measures, Lanarkshire.

RECENT STUDIES OF SHELLS OF THE
COAL MEASURES

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DURING the last twenty years much of the work that has been done
on the stratigraphy of the British Coal Measures and on their
structure and environments of deposition has been profoundly
influenced by researches on certain fossil bivalve shells that occur
in these rocks—commonly in the roofs of coal seams, but also at
other horizons in the thickness of sandstones and shales (with
occasional fireclays and coal seams) that make up the rock succes-
sion of the Coal Measures. These molluscs lived in waters adjacent
to the swampy coastal forests, which were later transformed into
coal seams by the compaction and carbonisation of their vegetation.
The first stage in this process was flooding by the waters, doubtless
not fully marine, in which the bivalves lived. Hence the frequent
occurrence of these fossils in the roofs of coal seams. The fossil
shells are well known to miners, who call them " mussels," an
accurate term conveniently used by all Coal Measures geologists.
Examples of three genera are illustrated in Figs. 1 (Plate I), 5 and 10.

Sometimes mussels occur in enormous numbers, tightly packed
together in shell beds that may be three or four feet thick and
extend underground for miles. Such shell beds (" musselbands "
is the technical name) are important stratigraphical units and in
certain British coalfields have long been used as marker bands in
mining operations.

Mussels do not always occur in musselbands, however. In all
coalfields they may occur in mudstone or shale as more or less
isolated individuals, and particularly is this true of the South Wales
Coalfield. Here Professor Trueman and his colleagues of the
Geology Department in the University College of Swansea, investi-
gating the stratigraphy and structure of the coalfield, came to
realise that the mussels had value as stratal indices apart altogether
from segregation into musselbands. Their use in this way involved
some modification of the existing classification, and the consequent

recognition of mussel assemblages which were sufficiently well characterised to render possible the subdivision of the local Coal Measures into a succession of six zones. This zonal scheme was found to apply throughout the western part of the South Wales Coalfields, and controlling observations in the coalfields of North Staffordshire and the North of France suggested that it was generally applicable to other coalfields.

The publication of the results in South Wales (Davies and Trueman 1927) was quickly followed by application of the mussel zoning to the principal British coalfields, with some minor adjustments of the original scheme. Workers in other centres shared this task in close collaboration with Professor Trueman. Examples of the numerous practical applications of the use of mussels in the exploration and working of the British coalfields cannot be given here, but it may be specially noted that the officers of the Geological Survey have collaborated both in the routine applications of the work and in the advancement of our knowledge of these fossils and their distribution.

It is rather my object in this article to concentrate attention on the more general results that have followed from the researches on these extinct Mollusca, and to explain some of the difficulties which confront workers in this field.

One of the earliest results of these researches, and fundamentally the most important, was to place the broad stratigraphical inter-correlation of the British coalfields on a sound palæontological basis, and to reveal that the anomaly between the Scottish and Yorkshire successions, suggested by Kidston's palæobotanical classification of the Coal Measures, did not in fact exist (Dix, Pringle and Trueman 1930 ; Weir and Leitch 1936 ; Trueman 1936).

The occurrence of marine bands at various horizons in the Coal Measures has long been known. These bands of shale with marine fossils represent incursions of the sea which were the extreme manifestation of pulsatory downward movements of the crust. These movements took place throughout Upper Carboniferous times, and are recorded in many repetitions, more or less complete, of a small standard sequence of sedimentary rocks (Trueman 1948), which culminates with coal, representing the final stage in the shoaling of the sea and the production of swampy forests at sea-level.

The marine bands are most useful marker horizons and their accurate correlation from coalfield to coalfield is of the greatest importance. In the absence of stratigraphical criteria or suitable evidence from the marine fauna (mainly brachiopods and cephalopods), the recognition of their respective places in the context of

the non-marine mussel faunas becomes of importance. This aspect of Coal Measures correlation has been recently investigated in relation to rhythmic cycles of sedimentation by Edwards and Stubblefield (1948), who record ten marine marker bands in the Middle Coal Measures of Nottinghamshire and Derbyshire.

The chronology of the Coal Measures mussels, by establishing broad inter-coalfield correlation on a secure basis, has brought new light to other aspects of Upper Carboniferous geology. Thus in two Presidential Addresses to the Geological Society of London, Trueman (1946, 1947), interpreting and synthesising the work of himself and others in this field, has demonstrated the inter-relationships of the coalfields of Europe and North America in the context of their changing physical and geographical environment, and has related the structures of individual British coalfields to their early foundations and to major tectonic events connected with the growth of the Variscan Mountains.

The first of these addresses discusses the Coal Measures of Europe and North America, their palæogeographical environments and sedimentary rhythms in the framework of Naumann's concept of paralic (external coastal swamp) and limnic (intermontane) basins of deposition (Fig. 2). To the paralic basins belong the coalfields of Britain, North-Western Europe (Pas de Calais, Nord, Belgium, Limbourg, Westphalia) and the Donetz. The limnic basins, of which the Saar and the coalfields of Central France are the most important, were formed within the growing Variscan mountain chains, and appear to have been entirely cut off from the paralic basins. On the other hand, distribution of successive mussel faunas suggests that there was relatively free communication between the external basins from South Wales to the Donetz, doubtless by the way of the more or less brackish waters of the swamps that fringed the southern continent (Figs. 2 and 3).

The growth of the Variscan chain forms the basis of a tectonic classification of the British coalfields into those of the Foredeep (South Wales, Somerset, Kent, Forest of Dean) and those of the Foreland (all the remaining more northerly basins). Within the framework of this classification, Trueman, in his second Presidential Address, discusses with wealth of detail from all sources, the stratigraphy, correlation and structure of the British coalfields. The Foredeep (or deepening basin of deposition situated immediately in front of a growing mountain chain) may, under favourable conditions and within certain time limits, yield a nearly continuous record of sedimentation. In Coal Measures (Westphalian) times these conditions were most nearly satisfied in Britain by the western part
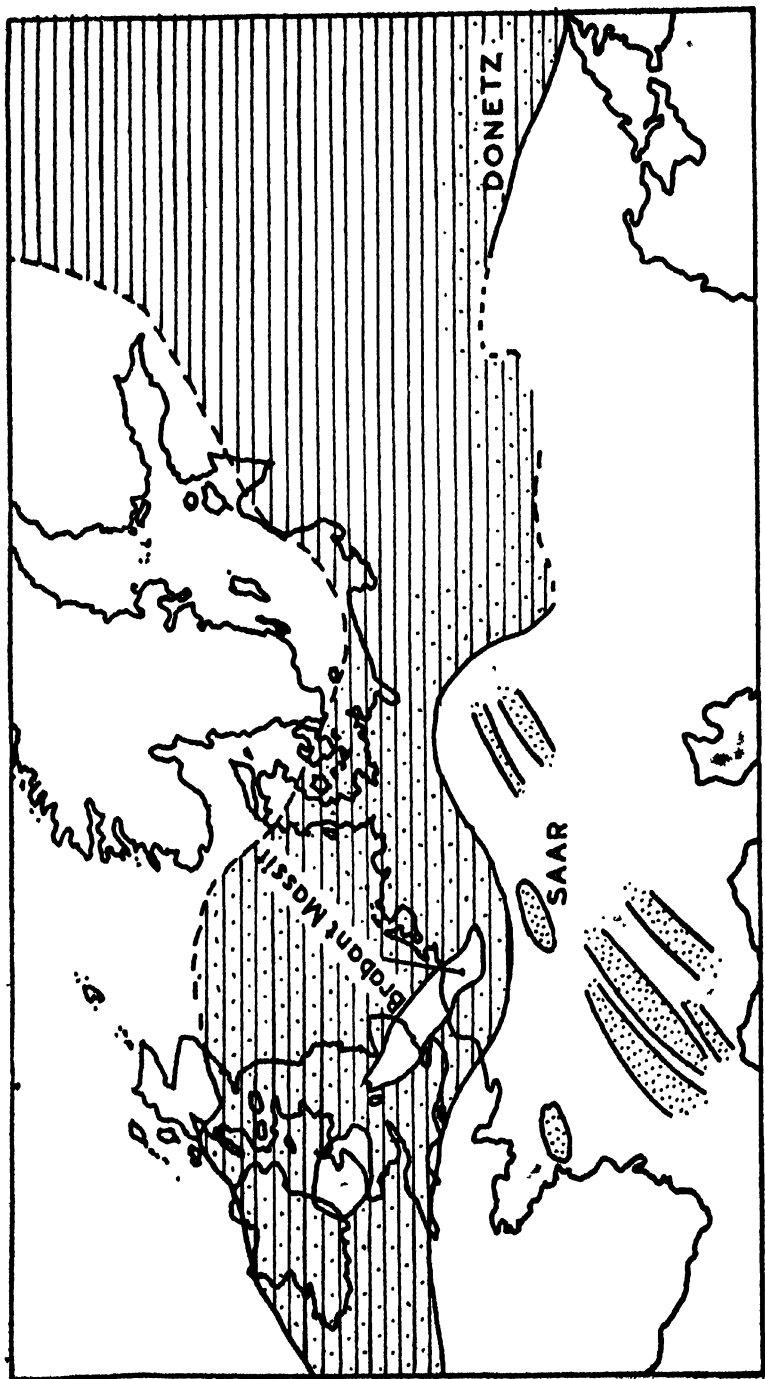
Fig. 2.—Reconstruction of the palæogeography of northern and eastern Europe in Upper Carboniferous times. Horizontal lines indicate predominantly marine facies lines, and dots, paralic facies in external basins; close dotting the limnic (intermontane) basins. (By courtesy of Dr. A. E. Trueman and the Geological Society of London.)

of the South Wales coalfield (Swansea area), and the succession
there is therefore taken as standard. Two divisions of the West-
phalian are recognised, and named after Welsh localities (Dix and
Trueman 1937) : Morganian (comprising the two upper mussel
zones) and Ammanian (the four lower zones of the succession).

In terms of this major subdivision, as well as of the narrower
zonal divisions, the structures of the various coalfields are examined
with reference to pre-existing tectonic structures (such as St.
George's Land, the Brabant massif, North Pennine massif and the
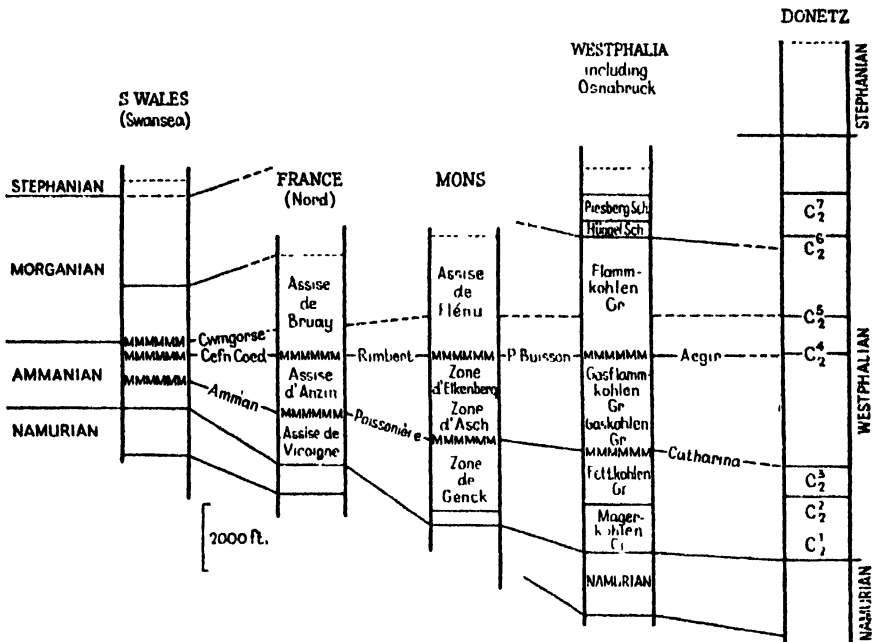
Fig. 3.—Comparative vertical sections of some European coalfields.
(MMM : marine bands.)

(*By courtesy of* Dr A. E. Trueman *and the Geological Society of London.*)

Southern Uplands) and to unconformities (gaps in the succession)
due to the local uplifts (and consequent non-deposition) which
reflected preliminary movements of the Variscan chain to the south,
premonitory rumblings of the major mountain-building which
followed the deposition of the Coal Measures and isolated them in
the separate basins or " fields " which we know today.

Some of these preliminary phases of the Variscan orogeny
(mountain-building) have been recognised on the continent by
Stille. The effects of the older of these (Sudetic and Erzgebirgian

phases) had previously been recognised in Britain (*e.g.* Hudson and Turner, 1933), but there is no evidence here for the Asturian folding of Stephanian age, so important in the limnic coalfield of the Saar. On the other hand, notable movements, unrecognised on the continent, occur in Britain in early Morganian times, and are especially important for their effect on the structure and sequence of British coalfields of the Variscan Foredeep (Fig. 4). The term " Malvernian
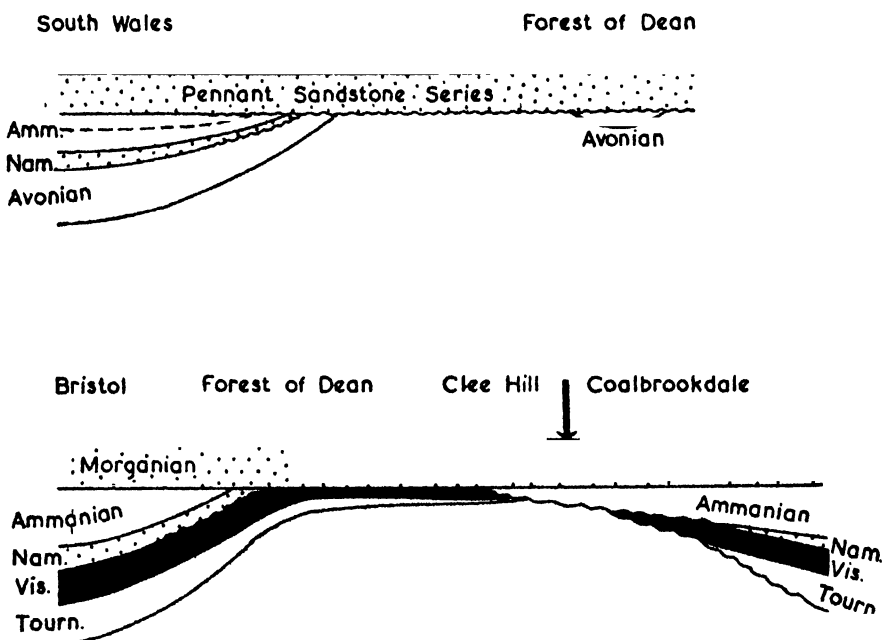
Fig. 4.—Diagrammatic sections showing the relations of the divisions of the Carboniferous from the east of South Wales to the Midlands. The arrow marks the probable belt of Sudetic Uplift.

Tournaisian and Viséan = Avonian, *i.e.* Carboniferous Limestone; Namurian = Millstone Grit.

Not to scale.

(*By courtesy of* DR. A. E. TRUEMAN *and the Geological Society of London.*)

phase " has been applied to these movements (Moore and Trueman 1939 ; Moore 1948).

Like their relatives *Unio, Anodonta*, etc., which inhabit rivers, lakes and canals at the present day, the mussels of the Coal Measures are highly variable in form at any given horizon (Fig. 5). There is no evidence that sexual dimorphism plays any part in this variability. Some of the biocharacters (*e.g.* those expressed by certain ratios, such as height/length, etc.) are suitable for statistical treatment. The first statistical analysis of a community of Coal Measures

shells was made by Davies and Trueman. The technique was elaborated by D. Leitch and R. A. Robb (Leitch 1940) who showed that, by the use of regression equations, accurate diagnosis of the essential character of a community could be made in respect, at least, of easily measurable shell-features.

A community of variable shells at a given horizon (say in a musselband) may be succeeded a few feet higher in the succession by a similarly variable community of the same genus, and com-
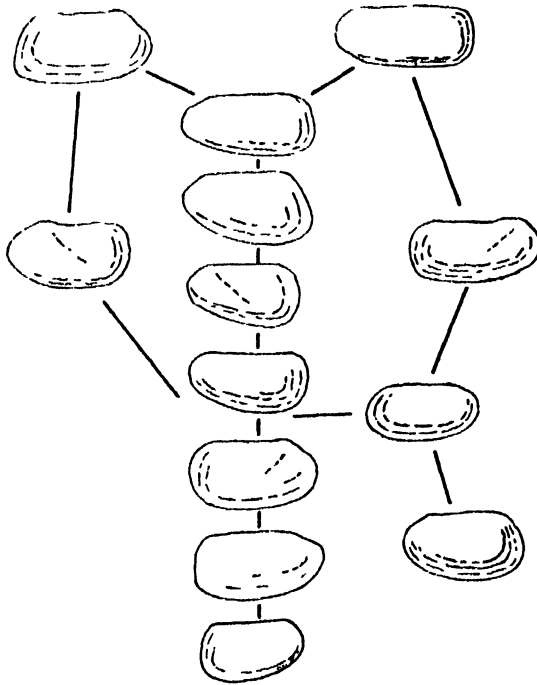
Fig. 5.—Variation in a community of *Anthraconaia salteri* in the Coal Measures of Lanarkshire.

(*By courtesy of* PROFESSOR D. LEITCH *and the Geological Society of London.*)

posed, like the first, of individuals that presumably interbred freely. The second community may show new variants, together with some that persist from the first horizon but are of different numerical significance in the later bed. When this is repeated in all coalfields at various horizons, through several hundred feet of that part of the Coal Measures which is most intensively mined (Trueman 1941) and therefore yields mussels in embarrassingly large numbers, the taxonomic complexities may be imagined. In face of this problem the artificial and empirical character of the binomial nomenclature
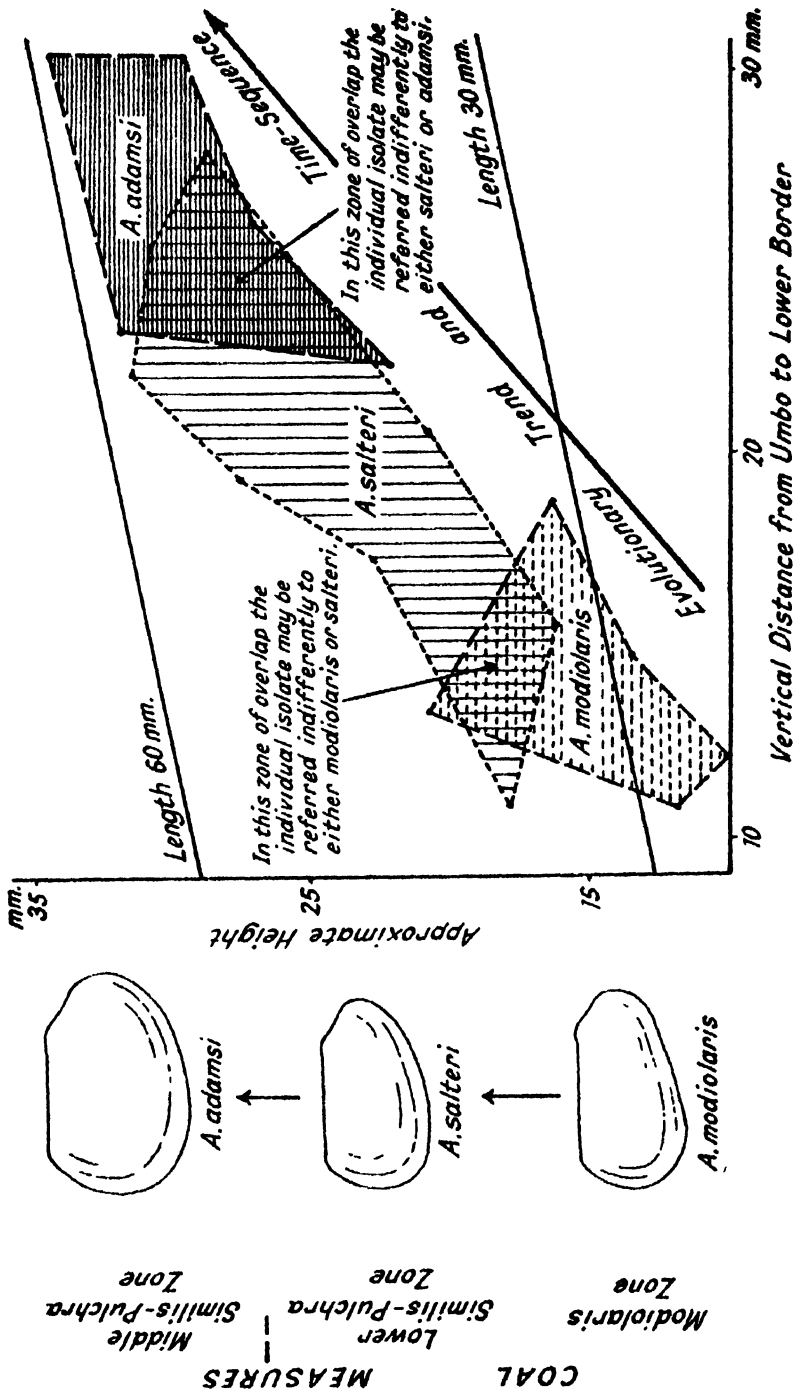
FIG. 6.—Variation and evolutionary trend in *Anthracomaia*.

(By courtesy of PROFESSOR T. NEVILLE GEORGE and the Royal Philosophical Society of Glasgow.)

stands revealed. The question has been discussed recently by Leitch (1940), George (1942), and Trueman and Weir (1945). Referring specifically to the work of Leitch (*loc. cit.*) and Eagar (1947) at Glasgow, George (1949) sums up the question as follows:

" In evolution naïvely regarded as a succession of ' intermediate links ' arranged in linear series, any given specimen may be allocated with precision and certainty to its particular (if arbitrarily defined) species. With this more profound understanding of the nature of the evolutionary process, the individual as such is often specifically anonymous, especially as knowledge increases of the variation-range and succession of evolving communities. Thus, according to the trend and degree of its variation from the norm, an isolated specimen of the [*Anthraconaia*] *salteri* community might justifiably be called *modiolaris*, or *salteri*, or *adamsi* (Fig. 6). It only becomes identifiable with certainty when it is seen in a context of its fellows, and is identified in terms of the nature of that context. Moreover, as an individual it is not always worth identification, for it is merely an incidental (and more or less atypical) isolate of the community to which it belongs.

Emphasis, as increasingly is the case in the systematics of living organisms, is thus becoming concentrated on the evolutionary diversification of whole communities."

Nevertheless, for practical reasons, the necessity remains to identify individuals (*e.g.* isolated shells obtained from an exploratory boring), and biological taxonomy is not yet ready to forsake Linnean procedure in favour of definition by formula. In their attempt to give a comprehensive account of these molluscs Trueman and Weir (*loc. cit.*) make free use of the contractions " aff." (*affinis*) and " cf." (*confer*) between the two components of the specific name, and the method of applying the former to the designation of individuals in a community is illustrated in Fig. 7.

" Cf." is used in the designation of a shell that is not known to be related to the holotype of a " species," though possibly showing in some features greater similarity to it than to any other described form. Absence of type material introduces a complication in the use of some of the older specific names, especially those proposed by Captain Thomas Brown in his *Atlas of Fossil Conchology* (1849) and his earlier paper in the *Annals and Magazine of Natural History* (1843), and much used in subsequent literature. In such cases reference is made to the original figure, but it may be urged that sanction of the use of neotypes by the International Commission on Zoological Nomenclature would be helpful.

With the exception of the Anthraconaias referred to in the above

quotation, no orthogenetic trend has been detected in these mussels, unless the progressive increase in size of *Anthraconauta* towards the end of its range may be so interpreted (Weir 1945) in conformity with Cope's Law.

It may be that the time involved (probably less than 30,000,000 years) was too short for the establishment of well-marked orthogenetic trends from the plethora of variation trends (incidentally *Anthraconauta* is the longest ranging of all the genera) ; possibly
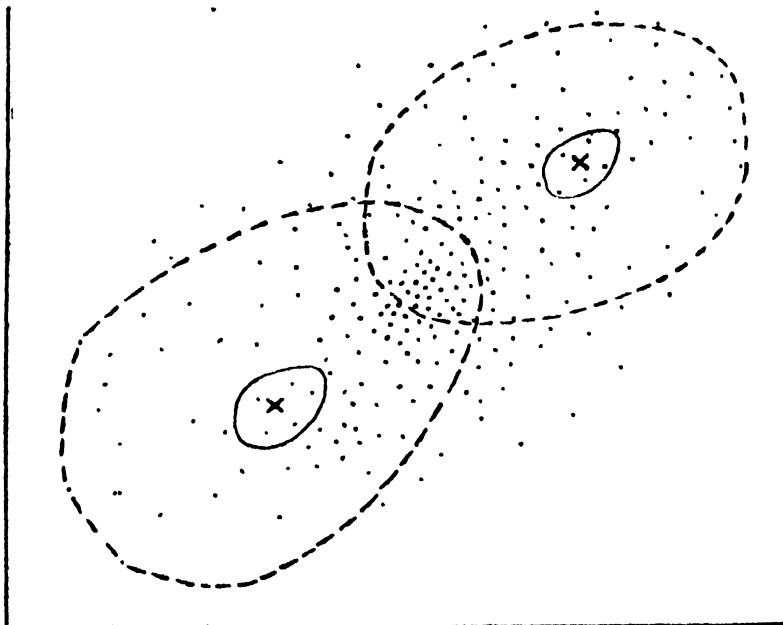
FIG. 7.—Representation of a community by scatter diagram.

Crosses mark the type specimens of two "species" ; around each the continuous line marks the limit arbitrarily ascribed to these species ; the broken lines enclose specimens which would be regarded as "aff." the species. Where these areas overlap, specimens might properly be named as having affinity to both species.

Neither of the type specimens corresponds with the mode of the community (although each may correspond with the modal forms of other communities).

(After TRUEMAN *and* WEIR, *by courtesy of the Palæontographical Society*)

orthogenesis is expressed at what is now taken as generic level (*Carbonicola* → *Anthracosia* ; although this represents a relatively sudden change rather than a trend) ; possibly trends are obscured by the welter of variants and may be revealed by systematic statistical analysis of all available communities in *all* the coalfields (*cf.* Figs. 5 and 6). It must be remembered that such analyses as have been done are few, and stand on the fringes of the problems as pointers of method for future work.

The problems of evolution and taxonomy in the mussel faunas of the Coal Measures have not been rendered easier by the revelations of Eagar's recent work (*loc. cit.*) in the Lower Coal Measures. Analysing the results of meticulous inch-by-inch collecting from a 30-ft. section of three-fold sedimentary rhythm at Honley, in Yorkshire, he found that there was correspondence between the character of a variable community and the nature of the sediment in which it was entombed, suggesting that shell-form tended to be influenced by the environment in which the animal lived. Following up this line of investigation Eagar (1948) has summarised the researches of European and American workers on the effects of different ecological stations on shell-form in the Unionidæ, and
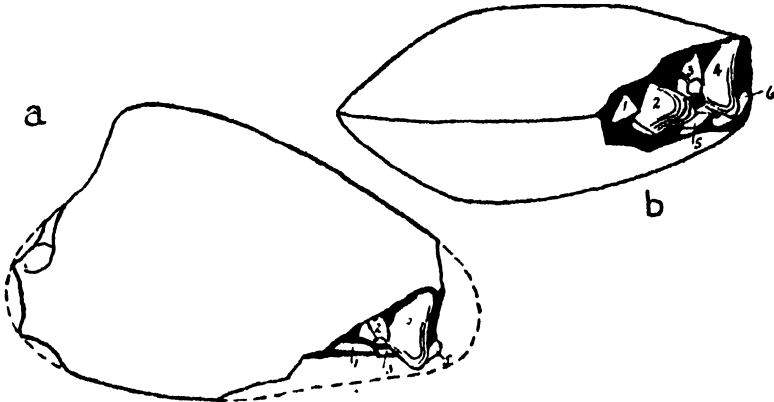
FIG. 8.—Shell of *Carbonicola*, broken at the posterior end and showing within the shells of several young *Naiadites*.

a, lateral view; *b*, ventral view showing that the valves are tightly closed.

(*By courtesy of* DR. RHONA MACLENNAN *and the* "*Geological Magazine.*")

has drawn attention to comparable modifications of morphology in the Upper Carboniferous mussels (Anthracosiidæ), in relation to changes in the grain size of the sediments in which they lived and were entombed.

Other fascinating lines of palæoecological research have been opened up by the study of these fossils. In the musselband above the Shotts Gas Coal of the Lanarkshire Coalfield Dr. Rhona MacLennan collected large shells of *Carbonicola*, which enclose within their tightly shut valves the shells of young *Naiadites* (MacLennan, 1943, and Figs. 8 and 9). Some of these young shells are in the position of growth, with anterior end applied closely to the inner surface of the *Carbonicola* shell, and the plane between

the valves nearly at right-angles to this surface (Fig. 9). These small shells can hardly have been introduced accidentally after the death of the host, for in no instance have small *Carbonicola* (numerically by far the dominant genus of the musselband) been found in like situation. It seems that the gaping shell of the dead *Carbonicola* provided a suitable settling-ground for the spat, affording shelter and a firm surface for byssal fixation in the muddy environment.

Subsequent closure of the *Carbonicola* shell may have been due to loss of elasticity in the ligament or to the weight of overlying sediment. It cannot have happened very quickly, however, as the largest enclosed *Naiadites* measures 25 mm. in length, the average of normal adults in the community.

The rate of growth of *Naiadites* is unknown, but it is unlikely that the largest of the enclosed specimens were less than two years old, several generations being represented within a single *Carbonicola*. During this time the shell of the dead *Carbonicola* must have remained open, its edges above the surface of the mud and the interior comparatively free from mud. These circumstances point to very slow accumulation of sediment.

The spiral tubes of the polychaete worm *Microconchus* (" *Spirorbis* ") are frequently found attached to shells, especially of *Naiadites* (Trueman 1942 and Fig. 10). Considerable numbers of these tubes frequently adhere to a single mussel valve. They are usually attached along the lower posterior edge of the shell, and at a corresponding position on growth lines (edges of the shell at earlier stages of growth). It is suggested, therefore, that the association may have been commensal, the Spirorbids attaching themselves preferentially along that portion of the posterior shell border nearest to the incurrent water stream, thus gaining an advantage in feeding. This commensal habit appears to have been particularly marked at certain times during the Carboniferous, and probably developed from attachment to the shells as a suitable substratum.

It may be noted that, like many related worms, some modern species of *Spirorbis* exhibit commensalism, and that *Spirorbis* grows very rapidly, a half whorl being formed in about four weeks, and

FIG. 9.—Section through a shell of *Carbonicola* showing two specimens of *Naiadites* in situ, their anterior ends touching the inner surface of the enclosing shell.

(*By courtesy of* DR RHONA MACLENNAN *and the* " *Geological Magazine* ")

more than one generation may develop in a single season. Therefore it is probable that a Spirorbid attaching itself to the shell margin of a *Naiadites* at a suitable season would reach maturity before shell growth left it stranded far from the edge.

Although occurring most frequently on *Naiadites*, *Spirorbis* has been observed attached to other genera of Coal Measure non-marine mussels, but not to *Anthracosphærium* and doubtfully to *Anthraconaia*. In *Carbonicola* and *Anthracosia* the region of attachment was narrower than in *Naiadites*, and it is possible to make some inferences regarding the posterior mantle border of these mussels.
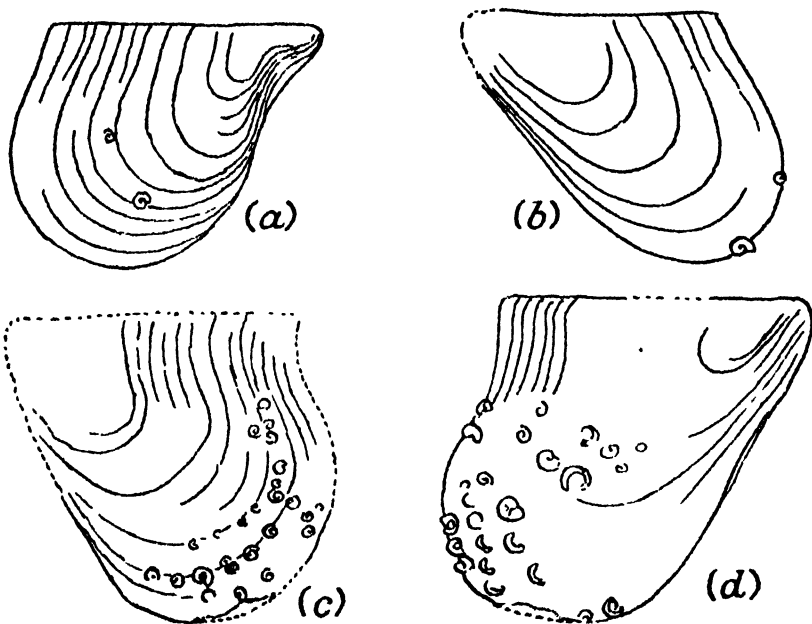
Fig. 10. - Spiral tubes of *Microconchus* [" *Spirorbis* "] attached to shells of *Naiadites*.
(*By courtesy of* Dr. A. E. Trueman *and the " Geological Magazine.")

In *Naiadites* the wide area of attachment suggests a mantle border with a broad incurrent region like that of the recent marine genus *Mytilus*, rather than a distinct siphon like that of *Dreissensia*, its analogue in recent fresh waters. A much narrower range of attachment on the shell surfaces of *Carbonicola* and *Anthracosia* indicates a narrower incurrent mantle border, comparable with that of the modern fresh water mussels *Unio* and *Anodonta*. The absence of any record of the attachment of *Spirorbis* to *Anthracosphærium* suggests that this genus may have had long pallial siphons, like its recent analogue, *Sphærium*. Such a siphonate mantle border would

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give no commensal advantage to organisms attached along the posterior edge of the shell.

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OPTICAL ACTIVITY: ITS STUDY, TERMINOLOGY AND USES

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OPTICAL activity (more precisely, optical rotatory power, often abbreviated to " rotatory power " or " rotation ") is the property of rotating the plane of polarisation of plane-polarised light. It is recorded as specific rotatory power $[\alpha]_\lambda^{t°}$, or molecular rotatory power $[M]_\lambda^{t°}$,

$$[\alpha]_\lambda^{t°} = \frac{\alpha_\lambda^{t'}}{ld} \text{ or } \frac{\alpha_\lambda^{t''}}{lcd} : \quad [M]_\lambda^{t°} = \frac{M[\alpha]_\lambda^{t°}}{100}$$

where $\alpha_\lambda^{t°}$ is the observed rotation in angular degrees at $t°$ C. of light of wavelength λ, produced by a column, l decimetres long, of liquid density d or of solution in which c is the fraction by weight, and M is the molecular weight of the optically active species. Molecular rotatory power allows for the fact that the beam of light is affected by different numbers of molecules of different molecular weights, in a column of given length and concentration.

Changes in rotatory power under fixed conditions of observation are described as " mutarotation " or " racemisation." Mutarotation refers to a change caused by the formation of a new centre of optical activity, whether additional to, or formed from, the original centre. Racemisation refers to loss of optical activity, whether partial or complete, due to chemical change at the centre of optical activity, with either loss of asymmetry or conversion to an optically inactive mixture of stereoisomers.

Optical activity is derived from a dissymmetry of structure, either in the crystal—for example in sodium chlorate, which loses its optical activity when dissolved—or in the molecule. There are certain requirements of molecular dissymmetry which must be satisfied if optical activity is to result (*see* Lowry). For the present purpose it is sufficient to take the absence of a plane of symmetry in the molecule as the main requirement, and most of the discussion is concerned with the " asymmetric atom," *i.e.* an atom which is attached by covalent bonds to dissimilar groups.

If the molecule is not to possess a plane of symmetry, the valencies of the asymmetric atom must extend in three dimensions : the most common example is the asymmetric carbon atom, which is situated inside a tetrahedron at the apices of which are the four attached dissimilar groups or atoms. Such a molecule can exist in one of two forms, which are mirror images of one another (enantiomorphs or stereoisomerides) : the molecules of one kind are dextrorotatory (rotate the plane of polarisation to the right) and of the other kind lævorotatory. A substance in which only one of the stereoisomerides is present is described as " optically pure " ; if both are present and in equal amounts the substance is racemic (*see* below) ; if both are present, but in unequal amounts, the substance is often described as " partly (optically) active " or " optically impure."

It should eventually be possible to define the absolute configurations of the two enantiomorphs of any given optically active substance, but this cannot be done at the present time, though the problem has received some preliminary consideration (*see*, for example, Rometsch and Kuhn). The relative configurations of members of certain series of compounds (*e.g.* the α-amino acids), in which one of the dissimilar groups attached to the asymmetric atom is varied, are known. The sign of rotatory power of a compound in such a series, (I (*a*), (*b*), (*c*), etc.), indicates which of the two relative configurations (I (*a*)) or (II) it possesses. Relative configurations can be deduced with complete certainty from
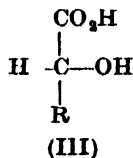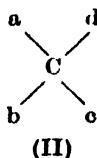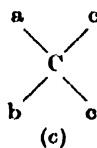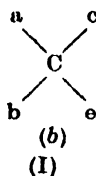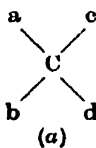
reactions in which it is known that the bonds of the asymmetric atom are not disturbed ; for example, in Freudenberg's establishment of relative configurations in the series (III) (R = $CH(OH)CO_2H$, CH_2CO_2H, CH_2NH_2, CH_2OH, CH_2Br, CH_3). Reactions in which one of the bonds of the asymmetric atom is broken can also be used if it is known whether or not inversion of the configuration of

the molecule occurs. Relative configurations can also be deduced, though with less certainty than by the above chemical method, from the observation that the rotatory powers of members of a configurationally related series are changed in the same direction by changes in physical or chemical conditions, e.g. by alterations in temperature, solvent, or ionic charge on substituent groups.

Since the sign of rotatory power may change, e.g. with alterations in solvent or temperature, it can only be related to configuration when determined under specified conditions. Originally, the prefixes d- and l- were used for the two signs of rotation. Later d- and l- came to be sometimes used for the two relative configurations, and (+)- and (−)- were then introduced for signs. The usage of (+)- and (−)- at the present time is unambiguous, but that of d- and l- may be ambiguous and is being abandoned.

Since the occurrence of rotatory power is dependent on the groups attached to the asymmetric atom being dissimilar, it is reasonable to suppose that its magnitude may be related to some properties of these groups. Chemists have deductively shown that there is such a relation with the polarities (in the chemist's sense) of the groups (see the work of Betti and of Rule, summarised by Lowry). Mathematicians have approached the problem inductively, and from consideration of, for example, the masses, volumes or polarisabilities in an electric field of the dissimilar groups, or of the possibility of electronic transitions therein, have calculated rotatory powers for certain substances, which seem to be of the right order of magnitude (Boys ; Born ; Condon, Eyring et al. ; Kauzmann, Walter and Eyring). Similarly, in the study of solvent-effects on rotatory power, a relation has been traced, to a limited extent, between the dipole moment of the solvent and the specific rotatory power of the solute, (Rule : see Lowry, op. cit.) and expressions have been deduced which at least lessen, if they do not entirely remove, the dependence of rotatory power on the refractive index of the medium (Beckmann and Cohen ; Rule et al.).

Optical rotatory dispersion is the variation of rotatory power with the wave-length of the polarised light. The rotatory dispersions of many compounds in transparent regions of the spectrum can be expressed by an equation of the form put forward by Drude (see Lowry, op. cit.) :

$$\lambda_\lambda = \sum \frac{kn}{\lambda^2 - \lambda_n^2}$$

the k's being numerical constants and the λ_n's being wave-lengths (" characteristic wave-lengths "). Indeed, it is possible that there

is a Drude equation to fit the rotatory dispersions of each optically active substance in transparent regions of the spectrum. It is, however, desirable that the calculations of the Drude constants should be based on observations which cover a wide range of wavelengths, extending as far as possible into the ultraviolet.

When the rotatory dispersion can be compared with the absorption spectrum of the compound, it is found that the characteristic wave-lengths lie within absorption bands. Optical activity is derived from a difference between the refractive indices of the substance in right- and left-circularly polarised light, and this originates in disturbances of valency electrons (shared or unshared). Though it may be that all the valency electrons in a compound can in principle contribute to its rotatory power (Kuhn), it is rarely that more than two Drude terms are required to cover the dispersion: this simplification may be due to cancellation of terms of opposite sign, or combination of more than one into one complex term, or to the contributions of certain terms being too small to be detectable.

The excitation energy of shared electrons is usually so great that it only occurs on absorption of light in the vacuum ultraviolet. The ordinary ultraviolet absorptions correspond to excitation of unshared electrons. One-term Drude equations are characteristic of substances whose absorption bands lie in the far ultraviolet : for example, the secondary aliphatic alcohols have a characteristic wave-length at about 1500 A, which is probably a composite of electronic transitions of unshared electrons on the oxygen atom, and of electrons in C—H, C—C, C—O and O—H links. If a compound contained two formally asymmetric atoms, and these gave rise to absorption bands of widely different wave-lengths, then presumably at least two Drude terms would be required to cover its rotatory dispersion. Most of the two-term equations which are on record, however (they are not numerous), appertain to substances which contain only one formally asymmetric centre and in addition contain a chromophoric group which has an absorption band of comparatively long wave-length : for example, an ethylenic link or a ketonic group. According to Kuhn's theory, all the possible electronic transitions which may occur in an optically active molecule influence each other (" vicinal action "), but in a simplified presentation it may be stated that one of the characteristic wave-lengths in the Drude equation of such a compound corresponds to an absorption band associated with the chromophoric groups, *i.e.* of comparatively long wave-length, and the other is a composite term of shorter wave-length, similar to that in one-term equations ; the term of longer wave-length usually makes the greater numerical

contribution to rotatory power, and provides the clearest illustration of "induced anisotropy" as defined by Kuhn. The expression "induced anisotropy" is preferable to "induced dissymmetry" because there is no reason to suppose that the chromophoric groups become dissymmetric in the stereochemical sense, as in

$$\begin{array}{c} R' \\ \diagdown \\ R'' \diagup \end{array} C=O \quad \rightarrow \quad \begin{array}{c} R' \\ \diagdown \\ R'' \diagup \end{array} C \diagup^{\nearrow O}$$
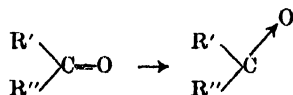
There is a relation between induced anisotropy and partial asymmetric synthesis, which is the formation of an unequal mixture of diastereoisomerides when a new centre of asymmetry is formed in a molecule which already contains an optically active atom (*see* Lowry; Ritchie). Partial asymmetric synthesis usually involves addition to an unsaturated group, *e.g.* the reduction of the (—)-menthyl ester of benzoyl formic acid (IV) to the ester of (—)-mandelic acid (V), which yields the optically active acid (VI) (MacKenzie). The anisotropy induced in the π electron-orbitals of

$$\underset{(IV)}{\underset{O}{\overset{H}{\underset{\|}{Ph.C\;CO_2.Menthyl}}}} \rightarrow \underset{(V)}{\underset{OH}{\overset{H}{\underset{|}{Ph.C.CO_2.Menthyl}}}} \rightarrow \underset{(VI)}{\underset{OH}{\overset{H}{\underset{|}{(\,-\,)\;Ph.C.CO_2H}}}}$$
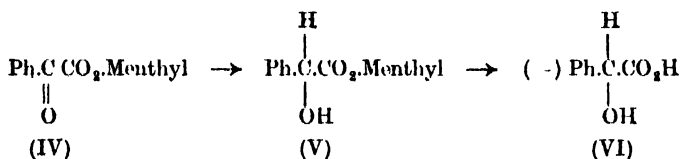
the ketonic groups by the presence of the optically active menthyl radical results in preferential formation of one of the two configurations in the $-C\diagdown^{\overset{\diagup H}{}}_{OH}$ groups formed on reduction of $-\underset{\underset{O}{\|}}{C}-$. A number of types of partial asymmetric synthesis have been described; a list is given by Balfe and Kenyon.

Absolute asymmetric synthesis, which is the formation of an unequal mixture of stereoisomers when an asymmetric atom is formed in the absence of any other centre of asymmetry, is less well established. The possibility of its occurrence attracts attention because naturally occurring substances which contain asymmetric atoms are almost always found as only one of the possible stereo-isomers. Given the occurrence of an optically active substance (*i.e.* a collection of dissymmetric molecules in which one stereoisomer preponderates over the other), the formation of others in a variety of ways can be envisaged : but the mode of formation of the first optically active substance requires explanation (*see* Mills, 1932;

Ritchie). Asymmetric decomposition has been observed : a small rotatory power is reported in the products of the photochemical decomposition of humulene nitrosite when irradiated with circularly polarised red light (*see* Lowry).

When an asymmetric atom, or other source of asymmetry, is formed by synthesis in the absence of any optically active centre, equal proportions of the two stereoisomers are produced ; in the liquid state (solution or homogeneous) they form a mixture— " racemic mixture ". On crystallisation, the racemic mixture may separate either as a conglomerate or as mixed crystals if the (+)- and (−)- forms are isomorphous ; or a racemate may be deposited. A racemate is a compound which exists in the solid state within a certain range of conditions, *e.g.* of temperature. It bears some analogy to the alums, and some of its physical properties (*e.g.* melting-point or solubilities) are different from those of the (+)- or (−)- forms, which are identical in all respects except optical rotation.

Substances in which the two halves of each molecule are mirror images, *e.g.* tartaric acid (VII), may exist in a form which is optically

$$
\begin{array}{c}
HO \quad H \\
\diagdown \mid \\
C-CO_2H \\
\mid \\
C-CO_2H \\
\diagup \mid \\
HO \quad H \\
(VII)
\end{array}
$$
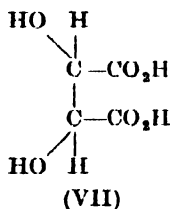
inactive because one-half of the molecule has the (+)-, and the other the (−)- configuration ; these are known as *meso*-forms and the possibility of their separation into stereoisomers does not arise.

The preparation of optically active substances usually involves their separation from the synthesised racemic mixture or racemate ; the separation is commonly described as (optical) resolution. If the two optical isomers differ in crystalline form, they may be separated by hand, as Pasteur did with the (+)- and (−)- sodium ammonium tartrates. If the substance undergoes enzyme-catalysed reactions, then it is often found that one optical isomer is preferentially removed, leaving an optically active excess of the other isomer. By far the most common method, however, is to combine the racemic substance with an optically active substance, *e.g.* a (±) acid with a (+)- base. The two forms produced, (+)- acid (+)- base and (−)- acid (+) base, are not mirror images and are known as diastereoisomerides. It is a fact that diastereoisomerides are distinct species, as illustrated by the sugars ; for the simplest

example, compare D-threose and D-erythrose. When the optically active resolving agent is covalently attached to the racemic substance, it is then to be expected that the two forms can be fractionally separated by physical methods, e.g. distillation, crystallisation or dissolution. Often the resolving agent and the racemic substance are linked in salt formation, though whether the salts are fully ionised may be open to question. If a deficiency of the resolving agent is caused to react with the racemic substance, it may react preferentially with one of the stereoisomers, so that the unreacted residue is optically active. A deficiency of the resolving agent may also be used in resolution by crystallisation, the separation then involving the difference in solubility between, for example, (+)-base (−)- acid and (--)- base hydrochloride.

Being a property which can easily be measured with a high degree of accuracy, optical activity is used for many analytical purposes. It has the advantage of being directly related only to the optically active substances in the solution under examination, and its sensitivity to solvent effects can be used with profit, since a solvent can be chosen in which the rotatory power is comparatively high, and so the more accurately measured. Its analytical uses, for example in the examination of sugars, are well known : a single observation can establish the concentration of one sugar in solution. Its sensitivity to chemical changes (e.g. the hydrolysis of sucrose, $[\alpha]_D + 66 \cdot 5°$, to a mixture of glucose and lævulose with $[\alpha]_D - 40 \cdot 5°$) or physical changes (e.g. the rotatory power of the mixture of equal parts of dextrose and lævulose passes through zero at a raised temperature, because lævulose has the higher temperature coefficient of rotation) can also be useful, enabling the composition of a mixture of several optically active substances to be deduced from several observations.

An extension of the analytical uses of optical activity is its application to the study of chemical equilibria. The rapidity and accuracy with which it can be measured, and the fact that the polarimeter tube can form a temperature-controlled reaction vessel, are in many cases of particular advantage in this respect. Thus Wilhelmy's measurements of the rate of hydrolysis of cane sugar gave an experimental foundation for the law of mass action, and later rate measurements on the same reaction by Ostwald and by Arrhenius were important in the development of the theory of ionic dissociation. The rate of mutarotation of reducing sugars (i.e. the formation of the equilibrium mixture of the isomeric configurations of the α-carbon atom) has been used as a basis for discussion of the theory of unimolecular reactions (Kendrew and

Moelwyn-Hughes). Other examples of the use of optical activity in studying the interconversion of labile isomerides have been reviewed by Turner and Harris.

Measurements of optical activity have been used as a guide to molecular configuration, notably in the sugar series (van't Hoff's *Principle of Optical Superposition*, Hudson's *Isorotation Rule* : see Lowry, *op. cit.*) and the sterols (Barton and Klyne). The principle of this procedure is that the partial rotations of individual asymmetric atoms in a molecule containing several such atoms is independent of the configuration (van't Hoff) or structure (Hudson) of the other asymmetric atoms ; thus the configuration of one of these atoms can be deduced from the rotatory power of the substance if the partial rotations of the other asymmetric atoms are known. The method assumes that the individual asymmetric atoms do not affect each other's partial rotations in the visible spectrum, and is therefore likely to apply only to substances which exhibit simple rotatory dispersion.

In the study of the spatial distribution of the atoms, or groups of atoms, in molecules, optical activity is the only physico-chemical property which is applicable. It could be argued that in its origin the method was empirical, since the reasons why spatial dissymmetry gives rise to optical activity were hardly understood, but it became established by such a wealth of practical observations that its validity cannot be questioned. Optical activity of liquids or of substances in solution is evidence of dissymmetry within the molecules. This may be due to the presence of an asymmetric atom, for example, a quadricovalent atom of carbon, nitrogen, phosphorus, arsenic, silicon, tin, or a tercovalent atom of sulphur, selenium, tellurium. It may be molecular dissymmetry in which the molecules have no plane of symmetry though they do not contain an asymmetric atom (*see* Lowry, *op. cit.*) ; the first example of this type was provided by Werner (1912), who obtained the
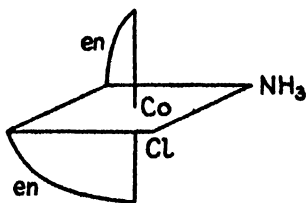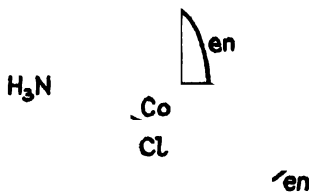
VIII   IX

optically active forms VIII and IX of the complex cobalt cation $[en_2Co(NH_3)Cl]^{++}$ (en = ethylene diamine).

A certain discretion is required in interpreting some parts of such work. Failure to resolve a substance into stereoisomerides does not prove the absence of asymmetry. It may be that the experimental conditions for the separation have not been found ; or that the substance has an immeasurably small rotatory power, which is probably the reason why it has not been possible to resolve substances in which the replacement of a hydrogen atom by deuterium has made a carbon atom asymmetric (Buchanan ; Brown and Groot). It may be that the atom which is presumed to be asymmetric has, in fact, the required tetrahedral configuration, but of such a lability that one stereoisomer passes into the other so rapidly that only the racemic mixture can be isolated ; this is probably the reason why asymmetrically substituted ammonias have not been separated into optically active forms (Maitland ; Kincaid and Henriques). Furthermore, the delicacy with which optical activity can be measured, and the very wide range of numerical values within which the optical activity of a substance may lie, can give rise to erroneous conclusions, since an observed rotation derived from a very small proportion of an impurity of high rotatory power may be ascribed to a not unreasonably low rotatory power of the major component. This was the basis of the conclusions, which have since been amended (Kornblum, Lichten, Patton and Ifflend ; Weissberger), that tercovalent carbon atoms bearing electrical charges, in the salts of *aci*-nitro compounds and in diazo compounds, can be sources of optical activity.

Given that the optical activity of a compound has been correctly ascribed to an asymmetrically substituted atom, it remains to consider what conclusions may be drawn about the structure of the molecules of the compound. It may be concluded that the valencies of a quadricovalent optically active atom are directed towards the four apices of a tetrahedron, and that the atom is somewhere inside the tetrahedron ; or that a tercovalent asymmetric atom and the three substituent groups are situated at the apices of a tetrahedron. But the observation of optical activity does not give any evidence that the tetrahedron is regular, or otherwise. Nor does it throw any light on the electronic make-up of the bonds, beyond the fact that they are covalent, not electrovalent. Thus the

$$S^{\oplus}$$

$$R'$$
$$R'' \qquad R'''$$

(X)
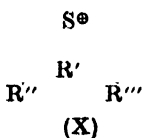
observations of optical activity in sulphoxides (x), $R''' = O$,

(Phillips; Harrison, Kenyon and Phillips) and sulphonium ions (x) (Pope) show that in both types of compounds the sulphur atoms and their three substituents are so placed with respect to one another that two stereoisomeric configurations can exist ; *i.e.* tetrahedrally. The optical activity of sulphoxides does not, however, provide information about the distribution of electrons in the sulphur-oxygen bond, which in fact is little different from that in a carbon-oxygen double bond (Phillips, Hunter and Sutton ; Sutton).

On the other hand, the occurrence of optical activity may on occasion suggest a type of molecular structure which can be accepted because it is more plausible than any alternatives, and regarded as established when supported by a sufficient body of evidence. Thus the observation of optical activity in *o*-substituted diphenyl derivatives (XI and XII) was early realised to be best explained by the

XI   XII
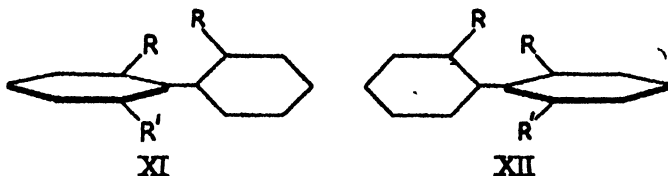
assumption that the axes of the two benzene rings are co-linear (Turner and Le Fevre ; Bell and Kenyon ; Mills, 1926). In unsubstituted diphenyl the rings can rotate freely about the common C—C axis, but appropriate *o*-substituents restrict this rotation and do not allow the rings to be coplanar. The molecule, therefore, has no plane of symmetry. This hypothesis of restricted rotation is now supported by such a wealth of evidence, both in the diphenyl series and in others (for an example of restricted rotation about a Ph—N bond, *see* Mills and Kelham), that it may be regarded as definitely established.

Optical activity has a fairly wide application in the study of the mechanism of reactions of aliphatic carbon atoms, since it is often possible to prepare model substances in which the key carbon atom is optically active. It is not generally applicable to the study of aromatic reactions, because aromatic carbon atoms cannot in general be a source of optical activity, but it has been used in connection with diphenyl derivatives, in which the *o*-carbon atoms can be regarded as such a source (*see* above), if their substituent groups can impose the molecular dissymmetry which gives rise to optical activity.

There are three stereochemical outcomes of a reaction at an aliphatic carbon atom : the product may be optically active with

the same configuration as the original material, or it may be optically active with inverted configuration, or it may be racemic. Retention of configuration may be due to one of two mechanisms : in one, all the four atoms attached to the asymmetric carbon atom remain undisturbed, and group replacement occurs on the further side of one of these atoms, as in the most common mode of alkaline hydrolysis of carboxylic esters (XIII). In the other, the entering group is held on the same side of the asymmetric atom as the group which it replaces. The simplest example of this type is in the halogenation of secondary alcohols by thionyl chloride or by phosgene : under certain conditions, an intermediate sulphinoxy chloride (or a chloroformate) is produced, from which the chloride is formed with elimination of sulphur dioxide (or carbon dioxide), as indicated in (XIV) (Cowdrey, Hughes, Ingold *et al.*). The first of these
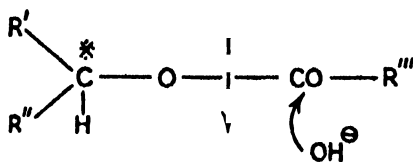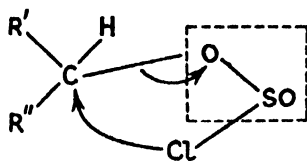
XIII   XIV

mechanisms evidently must produce complete retention of configuration, while the second may be, and usually is, accompanied by a certain amount of racemisation, though the difference can hardly be used for diagnosis.

When the product of the reaction is racemic, then it is concluded that the central (asymmetric) carbon atom has passed through a phase in which it has momentarily been covalently attached to only three groups and therefore assumes a planar configuration.

When the product of the reaction is optically active, and its configuration is the mirror image of that of the original substance, it is assumed that the central carbon atom has at no stage been attached to only three groups, but that in the transition state the replaced group and the entering group have been held on opposite sides of the central carbon atom.

If the reacting substance is optically pure, then the reaction in which the bonds of the asymmetric carbon atom are not disturbed gives optically pure products. The other reactions which give optically active products are as a rule accompanied by some racemisation, and that which gives a racemised product does not always give one which is entirely racemic. It is desirable from the present point of view to classify the reaction products as substantially

optically active (whether of retained or inverted configuration) or substantially racemic, and to base the discussion of mechanism on these major features, ignoring the effects of minor side reactions. If the reaction product contains optically active and racemic products in comparable amounts, then the interpretation of mechanism becomes more difficult : two concurrent mechanisms can sometimes be assumed, but the possibility that an optically active product has undergone a subsequent racemising reaction has to be borne in mind.

It is established by a variety of evidence that the most common mode of alkaline hydrolysis of carboxylic esters is one in which four valencies of the carbinol carbon atom are not disturbed, and mechanisms involving (XIII) are proposed. One of the lines of evidence is that if this carbon atom, C* in (XIII), is optically active, then the alcohol formed by the hydrolysis has the same configuration as the ester, and has suffered no loss of optical purity. It has, however, been found that when acid esters of dibasic acids with certain optically active alcohols are hydrolysed with dilute alkali, much racemisation occurs, but there is less racemisation during hydrolysis with concentrated alkali. The alcohols in question are those in which electron-releasing groups are attached to the carbinol carbon ; such as substituted allyl alcohols (*e.g.* (XV), $R' = CH_3$, C_2H_5 or Ph : $R'' = CH_3$ or Ph) or benzhydrols (*e.g.* (XVI), $R' = H$, $R'' = OCH_3$). Racemisation shows that the

$$R'.CH(OH)CH=CH.R''$$

(XV)

$$R'-\langle\;\rangle-CH(OH)-\langle\;\rangle R''$$

(XVI)
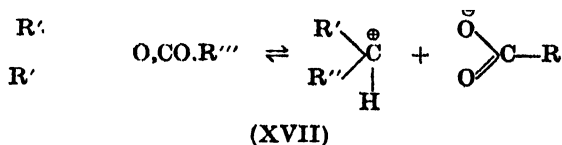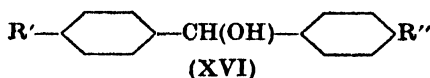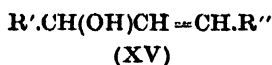
(XVII)

alkyl-oxygen C—O bond has been broken (XVII) and that there has been a transient existence of a tercovalent carbonium atom (probably carrying a positive charge). The argument suggests that the function of the dilute alkali is to bring the ester into solution in a medium (water) which favours the ionisation (XVII), and on account of its comparatively low concentration of hydroxyl ions does not favour the alternative mechanism (XIII). This argument

has been set out because it shows the separation between the observed facts (racemisation or retention of optical activity), the more or less incontrovertible conclusion drawn directly from them (breaking or not of the C—O bond) and the suggested mechanistic interpretation.

In the above reaction of carboxylic esters, observations of optical activity are used to indicate which bond in the reacting molecule has been broken. There is a large group of reactions of aliphatic carbon atoms in which the constitution of the products makes it clear which bond has been broken : we may take as examples the replacement of halogen by hydroxyl, and the conversion of alcohols to halides (XVIII) ⇌ (XIX). In these reactions,

$$\begin{array}{ccc}
\begin{array}{c}\text{R}' \quad \text{H}\\ \diagdown \diagup \\ \text{C} \\ \diagup \diagdown \\ \text{R}'' \qquad \text{Cl}\end{array}
&
\begin{array}{c}\text{OH}' \\ \xrightarrow{\hspace{2cm}} \\ \xleftarrow[\text{SOCl}_2,\ \text{etc}]{\text{HCl, PCl}_5,} \end{array}
&
\begin{array}{c}\text{R}' \quad \text{H}\\ \diagdown \diagup \\ \text{C} \\ \diagup \diagdown \\ \text{R} \qquad \text{OH}\end{array}
\\
\text{(XVIII)} & & \text{(XIX)}
\end{array}$$
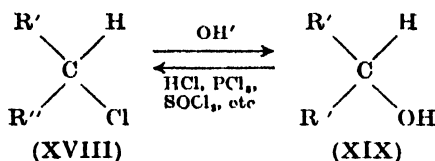
any of the three stereochemical results (inversion of configuration, racemisation, or retention of configuration) may occur, and each requires its particular mechanism. The inversion reaction is, of course, the Walden Inversion, the first example of which was reported in 1895 (the name is now commonly used to cover all three types of reaction). It was early realised (e.g. by Fischer, and by Werner, 1911) that, when inversion occurs, it is probable that the entering group has approached the face of the carbon tetrahedron opposite to the replaced group, before the latter has been released, and Lewis pointed out in 1923 the implication of this, that formation of the new bond and breaking of the old are concurrent. This view was adopted by Kenyon and Phillips, who also proposed that racemisation occurs if the replaced group separates from the molecule before the entering group becomes attached, leaving a tercovalent and hence racemised central carbon atom. Since the study of these reactions has recently been reviewed by Hughes, further detailed discussion is not necessary here.

Observations of optical activity can be used in the study of those molecular rearrangements in which one of the atoms which forms a new bond is optically active. If the product of the rearrangement is optically active, it is argued that the rearranging molecule has not split into two kinetically free fragments, i.e. that the rearrangement is intramolecular. If the product is optically inactive, it is argued that the rearrangement is intermolecular. The Hoffman, Lossen and Curtius rearrangements of derivatives of

amides, which are converted *via* isocyanates to amines, are examples of intramolecular rearrangements, the amines being formed with little, if any, loss of optical activity. These rearrangements may be represented by the general formulæ (xx) → (xxiii). The

XX   XXI   XXII   XXIII
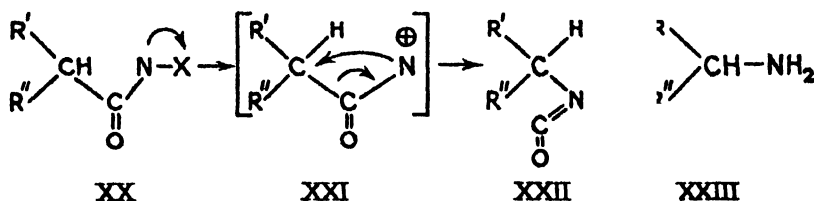
rearrangement of α-phenylethyl *p*-toluenesulphinate to α-phenyl-ethyl *p*-tolyl sulphone is an example of an intermolecular rearrangement : the product is optically inactive and is therefore concluded to have been formed by the mechanism (xxiv) → (xxvi).

(XXIV)   (XXV)

(XXVI)
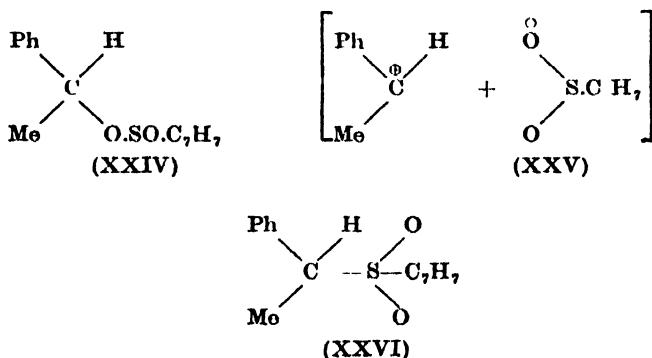
Even in the field in which it is applicable, the use of optically active substances is not the only method available for the study of reaction mechanisms. The constitution of the reaction products can be an indication of the mechanism : thus isomerisation in an alkyl group is evidence that the group has been free at some stage of the reaction. Cross reaction between the moieties of two molecules which are distinguished, *e.g.* homologously, and are undergoing the same kind of molecular rearrangement in admixture, is evidence that the rearrangement is intermolecular. Isotopically labelled atoms (mass- or radio-isotopes) can be used to follow the mechanism of reaction ; thus by use of O^{18} in the solvent water it was shown that in the alkaline hydrolysis of amyl acetate (Polanyi and Szabo), oxygen from the solvent appears in the resulting acid anion, and not in the alcohol, in accordance with mechanism (xiii). Kinetic

acc
does

studies can indicate whether the rate-controlling stage of the reaction is a change in one of the reactants, or involves a collision of two (or more) reacting entities. Each of these various methods has its advantages and disadvantages. The constitution of the reaction products must evidently be considered in formulating reaction mechanisms, but does not always directly indicate a mechanism. The other three methods do give an indication of what happens at some stage of the reaction, and so do directly bear on its mechanism. The methods which use optically active or isotopically labelled substances involve separation and purification of the reaction product, and so ensure that the discussion is based on major mechanisms and not on side reactions ; both give an indication of which bond in the reacting molecule is involved in the reaction, and both give results which are simple of interpretation. The use of optical activity has had the wider application, since in many reacting substances the key atom can be optically active. The kinetic method provides information about the molecules (radicals or ions) which are involved in the critical stage of the reaction, but not necessarily about the particular bonds which are involved. Studies of optical activity, provided that they are practicable and can be unambiguously interpreted (and both conditions hold in a wide variety of examples), provide a simple and valuable method for investigation of reaction mechanisms. Its simplicity accounts for its early use in this field ; nowadays, it is evidently desirable that the methods which subsequently developed should be used in conjunction with it, so that the conclusions may be the more firmly established.

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RECENT ADVANCES IN SCIENCE

ASTRONOMY. By Michael W. Ovenden, B.Sc., F.R.A.S., University Observatories, Cambridge.

An Interesting New Asteroid.—The first asteroid to be known, Ceres, was discovered accidentally by Piazzi on January 1, 1801, a propitious start for the century which was to give birth to modern astrophysics. The discovery was important, not only for the detection of a new class of planetary body of great significance to celestial mechanics, but also for the impetus which it gave to the calculation of orbits, for, in order to meet the emergency occasioned by the passing of the object into the morning sky, Gauss developed his famous method of calculating an orbit from only three observations. The next asteroid to be discovered by Olbers in the following year, was Pallas, and the intersection of the orbits of Ceres and Pallas led Olbers to suggest that the asteroids were fragments of a disrupted planet, a theory which has held the field, with modifications, for nearly a century and a half.

During the subsequent forty-three years, only three more asteroids were added to the list of discoveries, and it is understandable that at this time the discovery of a new minor planet was a matter of the greatest importance and the keenest interest. With the increasing application of photography to astronomy, and the greater telescopic apertures available, the number of discoveries soon multiplied, and in the years before the second world war the rate of discovery was as high as one per day. It is true that many of the supposed discoveries proved to be re-observations of known objects, and many others were single observations from which no orbit could be deduced, but the most recent compilation lists 1535 minor planets which have been officially named, and for which some form of orbit is known. The task of computing orbits has thus become formidable, and, for this reason alone, the astronomer who accidentally photographs the trail of an asteroid will, unless he be one who makes a special study of minor planets, give it little more than a passing glance.

The importance of these bodies to celestial mechanics remains, however, and objects with unusually high motions, or possibly

unusual orbits, may call for special attention. One such asteroid was photographed by Baade with the 48-inch Palomar Schmidt telescope on June 26, 1949. The trail from an hour's exposure was 2·7′ long, indicating a rapid apparent motion, in spite of the fact that the object must have been approaching its stationary point. Subsequent observations confirmed the motion of a degree a day, and Nicholson and Richardson have computed a preliminary orbit, an orbit which proved remarkable enough amply to repay the effort of computation (Richardson, *Pub. Astr. Soc. Pacific*, **61**, 162–5, Aug. 1949). The orbit is singular in more than one respect. It has a smaller mean distance from the sun, 90 million miles, than any other known minor planet or comet orbit, and an eccentricity so large that the body passes well within the orbit of Mercury, to within only 22 million miles of the sun, while at aphelion it is beyond the orbit of Mars.

The existence of such a peculiar orbit cannot but raise grave doubts as to the validity of Olbers' suggestion of a common origin for minor planets in a single major planet which suffered disruption. At the same time, it suggests forcibly a physical connection between asteroids and comets. Comets are recognised by their nebulous appearance, and possibly, although by no means necessarily, by the development of a tail when close to the sun. It used to be thought, perhaps almost by way of definition for doubtful cases, that the orbits of asteroids had low eccentricities while those of comets had high eccentricities. With this minor planet, whose orbital eccentricity is 0·752, and comet Schwassmann-Wachmann (I) with $e = 0·136$, to take only one comparison, the definition can clearly no longer hold, and the sole criterion of nebulosity remains. Even this is a difficult criterion to apply, and the minor planet Amherstia was originally listed as comet 1917 VI. A further similarity between comets and asteroids is the existence of " Families " of both types of object which bear some relationship to the major planets. If, as seems likely, a comet gradually loses its activity with every perihelion passage, due to the loss of matter by solar radiation pressure, then a former comet might well become indistinguishable from a minor planet. Indeed, there seems reason to believe that no real physical distinction can be drawn between the two classes of object.

At the time of discovery, the observed magnitude of the new minor planet was 16·0, but at its closest possible approach to the earth, a distance of 4 million miles, its magnitude should be only 12·5. From the apparent magnitude, the diameter of a minor planet whose albedo is known can be calculated. Unfortunately, this quantity is very uncertain. In order to obtain a consistent system of diameters,

the value assumed by Baushinger, 0·24, is generally adopted, which in this case gives a diameter of 0·9 miles. How much significance can be attached to such determinations is uncertain, for in the very few cases where a definite disc is observed and a direct determination of diameter can be made (*e.g.* Ceres, Vesta, Pallas, etc.) great differences in reflecting power from one asteroid to another are found. The largest asteroid known is Ceres, with a diameter of 480 miles, and, while few are known with diameters much less than a mile, there is probably a continuous variation from small asteroids to large meteors.

If the new asteroid does not rotate about its axis, Richardson has calculated that, at its nearest point to the sun, the surface temperature would approach 1000° F., when it might become faintly self-luminous. Many asteroids show periodic changes of brightness attributed to rapid axial rotation, however, and such rotation would much reduce the surface temperature.

An important possible use of the new asteroid may well be the determination of the mass of the planet Mercury. This is one of the least accurately known of the planetary data, for perturbations by the other planets are slight, and no satellite is available. The accepted value given by Backlund of 1/9,000,000 that of the Sun depends almost entirely upon observations of the perturbations of Encke's comet. While the comet approaches closer to Mercury than the asteroid, the latter's period of 343 days is only a quarter that of the comet, and therefore suffers more frequent perturbations. An illustration of our present uncertainty in the mass of Mercury is furnished by the recent analysis by Rabe of the orbit of Eros from 1926 to 1945 (note in *J. Brit. Astr. Ass.*, **60**, 119), who obtains for Mercury's mass a much higher value of 1/6,120,000 that of the sun.

The discovery by Baade of the asteroid with the smallest known mean distance is an interesting sequel to his discovery a quarter of a century ago of the asteroid Hildago, which has the greatest known aphelion distance.

RADIO " TWINKLING."—No apology is needed for the frequent reference in this series of articles to radio astronomy, for, when an important new branch of astrophysics is in the making, it is to be expected that significant new observations will be frequently reported. Not the least important advantages of the new astronomy was believed to be its relative immunity from the disturbing effects of the earth's atmosphere, which constitute such an important limitation to observational accuracy at optical wavelengths. While it remains true that the radio astronomer does not suffer the frustration of being " clouded out," some recently reported experiments indicate that he cannot entirely neglect the vicissitudes of the

terrestrial atmosphere (Smith ; Little and Lovell ; *Nature*, **165,** 422, 423, 1950).

The radio " point-sources " were first discovered by Hey, Parsons and Phillips, as a variable component of galactic radiation from the constellation Cygnus. The development of interference techniques for increasing the resolution of the radio telescope quickly led to the discovery of other sources, many at high galactic latitudes. Some 45 sources are now known in the northern hemisphere alone, but only the one in Cassiopeia is comparable in intensity with that in Cygnus. At first it was believed that the intensity of the Cassiopeia source was constant, but some variation was later reported (Ryle and Smith, *Nature*, **162**, 462, 1948).

It was originally supposed that these fluctuations were intrinsic properties of the radiation, and they were used to estimate the maximum physical dimensions of the emitting bodies   The first hint that all was not well appears to have been received by Dr. Pawsey and his collaborators in Australia. They found that, when simultaneous observations were made at widely separated sites, the fluctuations at the two receivers showed marked differences, suggesting a local origin for the fluctuations. With the Lloyd's Mirror technique used in Australia (see a previous article, SCIENCE PROGRESS, **38**, 275, April 1950) the sources are observed only at very low altitudes, where the extent and nature of ionospheric refraction effects might have been significant. Similar experiments were thus carried out by British workers. In one series, receivers at Cambridge and Jodrell Bank, Cheshire, were used, giving a separation of about 200 km., on a wavelength of 3·7 metres. Although at any given time the amount of fluctuation at the two sites was in general similar, no correlation of individual disturbances could be discerned. The variations must therefore have been produced either in the earth's atmosphere or, less probably, in the interstellar medium.

Experiments with variable base-lines of 100 metres to 170 km. were then undertaken. It was found that the correlation between the two receivers was complete for separations of 100 metres, partial for about 5 km., and non-existent for 170 km., giving definite indication of atmospheric origin. Little and Lovell have suggested that the localised disturbances of ionisation densities and gradients known to exist in the F-2 region of the ionosphere might give rise to sufficient change in refractive index for appreciable fractions of a Fresnel zone to suffer phase reversal, the resultant interference giving rise to intensity fluctuations in the received radiation, a process which would be essentially analogous to the well-known phenomenon of twinkling observed at optical wavelengths.

However, Smith has suggested that such a diffraction explanation is not entirely satisfactory, for two reasons. The first is that simultaneous observations on two widely separated wavelengths show great similarity, which would not be the case for any simple diᵣₐction mechanism. Furthermore, if the variations were due to irregularities of ion concentration in the ionosphere, some correlation of the degree of disturbance with magnetic storms, auroræ and other ionospheric phenomena would be expected, but such significantly is not the case. But whether the mechanism is diffraction or not, it would seem to be undoubtedly an atmospheric effect.

As well as these atmospheric fluctuations, which involve variations both above and below the mean value, very occasional " bursts " of large amplitude and short duration are observed simultaneously at two widely separated receivers. These may indeed be an intrinsic variation, but, in the light of earlier experience, it would be wise to reserve judgment and await further observations ; the atmosphere may hold more unsuspected traps for the radio astronomer !

RECENT EXPERIMENTS ON SEEING CONDITIONS.—The radio " twinkling " is a recent discovery, whereas its optical counterpart has been recognised for centuries. While there can be no doubt that its origin lies in some form of atmospheric turbulence, and that any physiological effects such as that proposed by Hartridge (*Nature*, **164**, 999, 1949) can at best be of secondary importance in the astronomical sphere, we can hardly claim to have a completely satisfactory picture of the mechanisms involved. Indeed, very little quantitative experimental observation of the effects of poor seeing conditions seems to have been made ; perhaps the general complexity of any meteorological phenomenon has been too great a deterrent.

The matter is of the greatest importance in practical astronomy, for the consequent changes of size and position of stellar images represent the greatest single limitation to the accuracy of astrometric measurements. Simple diffraction theory leads to an image diameter of 0·13″ for a 60-inch telescope, but in practice the photographed diameters, being the integrated records of many mutually displaced momentary images, are usually some 20 times this theoretical limit. This inefficiency is due almost entirely to poor seeing, the contribution of photographic diffusion effects being almost negligible.

Recently, a quantitative analysis of the various atmospheric factors contributing to poor resolution has been made by Gaviola (*Astron. J.*, **54**, 155, 1949). His interpretation begins with the

assumption that the atmospheric inhomogeneities take the form of inversion layers, an inversion layer being a stratum of warm air lying above a stratum of colder air, the " warmer " and " colder " referring not to actual temperatures but to " potential tempera-tures " which allow for the adiabatic lapse rate between the same regions of the atmosphere when in its equilibrium state. When a differential velocity exists between these two layers, boundary waves are supposed to be set up. Such a wave system will act as a series of weak lenses, alternately converging and diverging, and can be characterised by a wavelength L, a focal length F and a velocity V. The observed effects will, of course, be due to the superposition of various wave-systems at different heights, each producing its own characteristic effects, whose nature will depend upon the relationship between the aperture D and L, and the height H and F. The case of D < L/2 corresponds to the use of the naked eye, or a small telescope. Low waves, or waves of small amplitude where H < F would then give rise to the dancing of a fine image, but little change of brightness, or scintillation. If the height should be such that the eye or objective lies near the plane of the foci of the atmospheric lenses, then changes of both brightness and diameter of the image should result. For very high wave-systems, with H > F, the images should be large and steady. For larger apertures, with L > D > L/2, the images should be invariably larger than the resolution of the instrument, and showing scintillation again if H ∼ F. These predictions are in general agreement with practical experience, for twinkling of any kind is observed only with small apertures, which also show the smaller visual images.

The assumption of a single, regular wave train must be an oversimplification. In order to examine the extent to which the ideal conditions are reproduced in the atmosphere, Gaviola focused a camera on the main mirror of the 60-inch reflector at Cordoba. With exposures between 0·1 and 0·01 seconds, he was able to photo-graph the shadows of the inversion-layer wave-systems. In some cases, the overlapping of many different wave-trains produced a confused result, but frequently two or three individual wave-systems could be clearly seen. With such an arrangement, only waves with a suitable combination of H and F, and within a certain L-range, would have been recognised. In fact, wavelengths over the complete range from L ∼ 1 cm. to L ∼ 50 cm. were observed. The photographs clearly demonstrate that the state of atmospheric turbulence at any time can be represented to a surprisingly good approximation by a (small) number of inversion-layer wave-systems. The duration of a wave-train may vary from fractions of a second

to some days in extreme cases, the persistence of a short-wave system, L = 3 cm., being attributed to the prevailing westerly winds at Cordoba above an inversion layer at a height of 4000 m.

The demonstration of the existence of such coherent wave-trains led Gaviola to suggest that such a wave-train would be able to act as a diffraction grating, and he interprets the images produced by large telescopes, where D > L, in terms of this hypothesis. In order to observe such spectra, it proved necessary to avoid the dancing and pulsation effects, which he overcame by trailing the star images, for dancing would not affect the image size, and a few portions of the trail should give a width equal to the theoretical limit. When such trails were examined in detail, definite fine-structure emerged, which Gaviola believes to be due to the differing intensities of the various spectral orders. This interpretation is not without its difficulties, for in many cases the orders appear to be asymmetric, or the zero order may be apparently absent altogether, but, since the observed spectra, if the fine structure be indeed due to this cause, would be the combined effect of many separate " gratings " of various heights and characteristics, too much regularity is hardly to be expected.

The importance of this investigation lies not only in the information which it yields on the nature of the atmospheric processes involved in producing poor seeing conditions, but also in the suggestions made for overcoming, at least in part, these atmospheric limitations. Gaviola has estimated, from his trailed images, that any particular interval of perfect seeing lasts for only about $\frac{1}{50}$ second. If exposure-times of such short durations could be taken in any investigation, then selected exposures should have a definition approaching the theoretical limit. Such a procedure has been suggested by Hubble for solving the still vexed question of the existence of the " canals " of Mars, using the Hale telescope. However, exposure-time, with a given instrument, is not a quantity which is much at the disposal of the astronomer, and it remains to be seen whether even the 200-inch will have a sufficient light-grasp to record planetary details with such short exposures. With more modest apertures little, if any, work is available where such short exposures would be of any use. The application of the technique of trailing stellar images across the plate at a suitable speed (which would depend upon the magnitude of the star and the characteristics of the instrument) seems much more promising. If the fine-structure already described be visible, resolving powers close to the theoretical limit should be obtained, but, even if the speed is not large enough for this, the elimination of low-frequency dancing and pulsation and

the possibility of taking several measures on one plate would represent a great advance on present astrometric techniques. Gaviola and his colleagues have already applied these methods to the measurement of double stars. If future progress fulfils the promise of these early results, a new era of double-star astronomy may well open, when perturbations due to planets in double-star orbits, at present known in only two of the nearest doubles, may become a common feature of interpretation. With all that this would imply for cosmogony, it would indeed be a major astronomical advance. Gaviola also suggests that trailed star images should be taken as a preliminary to any photographic investigation, so that the present, admittedly inadequate, qualitative estimates of seeing conditions may be replaced by a standard quantitative scale.

One of the earliest critical examinations of " seeing " was made by Schlesinger (*Seeliger Festschrift*, 1924 ; *Mon. Not. R. Astr. Soc.*, George Darwin Lecture, 1927) who has justly been termed " the father of astrometry." It is interesting to note that one of the effects of the atmosphere to which he drew attention has yet to be satisfactorily explained. He found that early photographic measures of separations of faint stars were systematically more accurate than those of highly experienced visual observers, in spite of the latter's advantage in following the dancing of an image which causes enlarged integrated photographic images. This resulted from the fact that all stars are photographed at exactly the same time, while the visual observer makes independent settings on both stars. This would not be significant were it not for the fact that the star images over small areas of the sky have parallel motions, even under good seeing conditions, with periods of the order of a minute of time, and deviations of the order of a second of arc.

The problems of seeing so far considered have been treated from the standpoint of night observation. During the day, for the solar observer, the atmospheric turbulence is usually present to a much more marked degree, but the problem of steadiness of image may not be so serious, as very short exposures can be made. The solar observer's difficulties are dominated by atmospheric scatter, causing sky brightness and reduced contrast. Some quantitative analysis of sky brightness has recently been undertaken by Piaskovskaya-Fessenkova (*Astr. J. Soviet Union*, 26, 175, 1949), who has made the interesting discovery that a one-to-one relationship between the sky-brightness at a given distance from the sun and the degree of transmission does not exist. Instead, two distinct curves emerge from the observations, one believed due to scattering by particles (dust and smoke) and the other by molecules (water). The common

practice of estimating transparency from the brightness of the solar auriole may frequently be invalid ; even the scientist is not without his superstitions ! There are grave difficulties in the way of the accurate measurement of sky brightness near the sun, because solar light scattered within the detecting instrument is usually many times brighter than the sky light. Evans of Harvard has built a special photometer to give accurate relative intensities of solar and sky light (*J. Opt. Soc. Amer.*, **38**, 1083-5, 1948). When the observations of this instrument are examined, it is probable that further fine-structure in the relationship of transparency to scatter will be found, for it is unlikely that the scattering processes in the atmosphere are limited in number to two.

PHYSICS. By F. A. VICK, O.B.E., Ph.D., F.Inst.P., The University, Manchester.

SOME APPLICATIONS OF PHYSICS IN MEDICINE (PART II).—**1.**—In a previous article in this series (SCIENCE PROGRESS, **37**, 682, October 1949) some account was given of three current applications of physics in medicine, and it is intended now to give further examples to show how wide is the scope for the physicist who ventures to assist his medical colleagues.

It is well known that some of the most difficult physical measurements to perform accurately are those involving heat interchanges, and the difficulties are, naturally, even greater when such measurements are made on human beings. For the clinical determinations of energy exchanges, direct calorimetry involves so many awkward problems that most investigators have used indirect methods based on gas analysis. There is real need, however, for a direct-reading calorimeter with a reasonably short response-time to examine the effects of muscular activity, certain drugs, sudden changes in environment, etc. An interesting paper on the design of apparatus for this purpose has just been published (T. H. Benzinger and C. Kitzinger, *Rev. Sci. Instr.*, **20**, 849, Dec. 1949.) In principle the whole of the inside of a calorimeter containing a human being under test is lined with a thin layer of a moderate thermal conductor, and the changes of temperature difference across this layer are recorded continuously. Sin $= KA\theta/d$ cal. per sec., where K is the thermal conductivity of the layer of thickness d cm., A sq. cm. is the area and θ is the temperature difference between the two sides of the layer, a measurement of θ will be proportional to Q provided that K remains sensibly constant over the temperature range used. The temperature of the inner layer facing the subject in the calorimeter will determine his thermal environment, and this must not

vary much during an experiment. It is necessary, therefore, for the "gradient layer" to be thin, for the temperature fall across it to be small and for the exterior temperature to be kept constant. The calorimeter consists of a metal shell lined with thin uniform insulating material, the temperatures of the surfaces of which are measured by numerous thermocouples uniformly distributed over them. The whole calorimeter is immersed in a bath, thermostatically controlled.

Preliminary measurements and tests have been made with a small calorimeter 8 × 8 × 16 in. preparatory to the construction of a full-sized one 32 × 32 × 84 in. The walls are of aluminium plates $\frac{1}{4}$ in. thick, and one side (8 × 16 in.) is removable. The inner surfaces are enamelled for insulation and lined with the gradient layer, consisting of cellulose acetate 0·030 in. thick interlaced with copper and constantan strips 0·002 in. thick to form thermocouples, as indicated in Fig. 1. There is one thermojunction
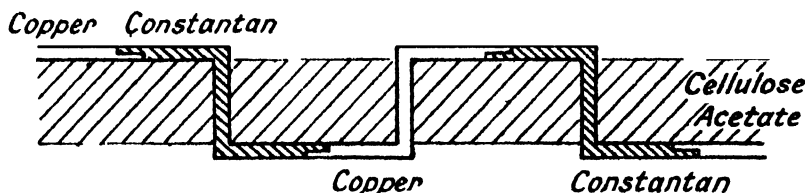
Fig. 1.

for each square 2 × 2 in., and they are all connected in series to form a continuous chain. Each junction is bonded to the cellulose acetate (alternately on each side) with rubber cement, and the total number is 160. The surfaces of the layer are covered with enamelled copper sheets 0·005 in. thick, which are coated with flat paint. The calorimeter was tested by hanging in it various electrical sources of heat, immersing the whole in a water bath, and measuring the thermal E.M.F.s generated. Errors amounting to about 1 per cent. of a human metabolism at rest would result from a change in temperature of the bath by 3·6° C. an hour, and it is easy to thermostat more accurately than this. The response was found to be reproducible, stable and linear. The "sensitivity" was 135 μV per cal./sec. If the subject is completely surrounded by a uniform gradient layer each unit area of which responds with the same thermoelectric E.M.F., then the total heat transfer is represented by the total measured thermo-E.M.F. and is independent of the position of the subject inside the calorimeter, the directions of heat flow and its distribution, and the shape of the calorimeter. The

temperature fall across the layer for each calorie per sec. flow is less than 0·05° C. There was no appreciable difference when the heat transfer was by radiation, conduction, convection and evaporation and condensation of water in various proportions.

To function for living subjects the calorimeter must permit exchange of gases during respiration. Also, to prevent accumulation of moisture, there must be a ventilating current of air. Heat would enter or leave the calorimeter by these air streams unless such air leaves at the same temperature and humidity as it enters. A considerable amount of heat is transferred to the inspired air in the lungs, and this must be measured. This is done by allowing the air entering and leaving the calorimeter to pass through heat interchangers immersed in the constant-temperature bath and recording the heat removed from the outgoing air by making it pass through another " gradient-layer " in the interchanger. Such a measurement also takes into account the heat interchanges resulting from the change of humidity of the ventilating air stream. For accurate measurements, the following conditions must be met : (a) exchange of heat in the connecting pipes must be negligible, (b) the heat interchange between the circulating air and cooling bath must be practically complete, (c) the thermal E.M.F.s generated in the gradient layers must be proportional to heat flow, and equal in all parts of the calorimeter and heat exchangers. If these conditions are satisfied, the total heat exchange can be measured by adding the thermal E.M.F.s in series.

Typical heat interchangers are described in the paper, and it was proved experimentally that the total heat measured under given conditions of generation was the same with or without circulation of air and whatever the distribution of heat between main calorimeter and heat interchanger in the air leads. The tests indicate that a " gradient calorimeter " appears to be reliable and convenient in use, and measurements made with the full-size instrument will be awaited with interest.

2.—In the previous article in this series (SCIENCE PROGRESS, **38**, 283, April 1950) some account was given of recent work in Denmark on the physics of the heating of buildings. Closely related to this is, of course, the determination of the thermal conditions under which human beings feel comfortable and work most efficiently. Dr. T. Bedford has now given (*Brit. J. Appl. Phys.*, **1**, 33, Feb. 1950) an account of work by him and others to determine these optimum conditions, bringing up to date pre-war reports. Measurements were made in twelve factories in a variety of industries of the temperature, humidity, air speed and radiation from the

surroundings at 4 ft. from the floor near the heads of seated workers carrying out light tasks. Temperature and air speed were also measured 6 in. from the floor. Skin temperatures on a hand, a foot and forehead of each worker were recorded, and also the mean surface temperature of the clothed body. Each worker's response to questioning was classified on the following 7-point scale.

TABLE I

1 Much too warm.
2 Too warm.
3 Comfortably warm
4. Comfortable.
5 Comfortably cool.
6 Too cool.
7 Much too cool.

These results were correlated with readings on various instruments, as follows :

TABLE II

Equivalent temperature	$r - 0\ 52$
Globe thermometer reading	$r - 0\ 51$
Effective temperature	$r - 0\ 48$
Air temperature (dry bulb)	$r - 0\ 48$
Mean radiant temperature	$r - 0\ 47$
Dry Kata cooling power	$r \mid 0\ 43$
Absolute humidity	$r - 0\ 12$

where r is the correlation coefficient, within $\pm 0\ 01$ standard error in each case. Equivalent temperature was calculated from the readings of Dufton's eupatheostat, which is a blackened cylinder 22 in. high and $7\frac{1}{2}$ in. in diameter, containing a heater thermostatically controlled at 78° F. The surface of the cylinder is then at 75° F., about the average for a clothed human body. The power absorbed to keep this temperature is measured, and rate of loss of heat is related to the temperature of the surroundings. The globe thermometer indicates the combined effects of radiation and convection and consists of a hollow 6 in. copper sphere, coated with matt black paint, and containing an ordinary thermometer with its bulb at the centre of the sphere. Effective temperature is a scale widely used by heating and ventilating engineers in U.S.A., and takes into account air temperature, air movement and humidity. It was determined empirically, by experiment. The Kata thermometer is an alcohol one with a bulb about 4 cm. long and 2 cm. in diameter. In use it is heated and the rate of cooling between two fixed temperatures determined. It is used mainly for the determination of local air movement.

It will be observed that there is little significant difference between the first five correlation coefficients of Table II, which was based on 2571 sets of observations. While atmospheric

humidity is of great importance when the temperature is high, at the room temperatures encountered it has comparatively little effect on the feeling of comfort. As a result of his measurements, Dr. Bedford gives comfort zones as in Table III below ; temperatures between which not less than 70 per cent. of people feel comfortable.

TABLE III

Equivalent temperature	.	.	.	.	. 58–66° F.
Globe thermometer reading	.	.	.	.	. 62–68° F.
Effective temperature	.	.	.	.	. 57–63° F.
Air temperature (dry bulb)	.	.	.	.	. 60–68° F.

These temperatures are distinctly lower than those found desirable in U.S.A. Dr. Bedford also discusses some of the other factors which determine comfort, e.g. the conditions which give rise to a feeling of " stuffiness." Recent work has confirmed that, with the same equivalent temperature, warm walls and cool air lead to a fresher feeling than walls at air temperature or cooler. As a result of all the measurements, Dr. Bedford lists the following requirements for a comfortable and invigorating indoor environment.

(i) A room should be as cool as is compatible with comfort (see Table III).

(ii) There should be adequate air movement but no draughts. At the temperatures usual in buildings in this country in cold weather air speeds below 20 ft./min. tend to cause feelings of stuffiness, whilst distinctly higher speeds are desirable in warmer weather.

(iii) The air movement should be variable.

(iv) The relative humidity should not exceed 70 per cent. and should preferably be well below this figure.

(v) The mean temperature of the solid surroundings should be above air temperature.

(vi) The air at head level should not be distinctly warmer than nearer the floor.

(vii) The heads of occupants should not be exposed to excessive radiant heat.

The work described is an interesting example of the use of physical measurements to make more quantitative rather vague expressions of feelings.

Some useful figures of the temperatures of various parts of the skin and in deeper tissues are given in a paper by L. G. C. Pugh (*Physiotherapy*, 36, 3, Jan. 1950). For a man normally clothed and resting in air at 70° F., the average skin temperature will be about 92·5° F. but may be as low as 82·4° F. on the exposed hands. The temperature of the deep tissues under the same conditions is

about 98·6° F., though measurements with a thermocouple show that the temperature of the blood returning to the heart from the liver is about 1·8° F. higher than that from the limbs. There is thus a temperature difference of about 6–7° F. between the deep tissues and the skin, and this is apparently effective over a depth of about 2 cm. These measurements enable calculations to be made on heat transfer through human tissues rather similar to those described for building materials in the last article (*loc. cit.*). Dr. Pugh gives figures illustrating the effect of a cold environment. Here again quantitative physical measurements are likely to yield very useful results.

3.—The stethoscope is perhaps the most widely used physical instrument in medical practice, but, except in its simplicity, it leaves much to be desired, especially for listening to heart sounds, etc., of such low frequencies that the ear is comparatively very insensitive. In recent years there has been increasing use of micro-phones, valve amplifiers and recorders, but some of them have been little more sensitive than the human ear. Improved methods are described and some typical results are given by A. Leatham (*Postgraduate Med. J.*, **25**, 568, Nov. 1949). Microphone and amplifier circuits contain filters (aided in some cases by acoustic filters attached to the microphone) to enable the low-frequency response to be relatively great when desired. Three frequency ranges are found convenient. Crystal microphones (Rochelle salt) activated by diaphragms are now much used. The microphone is attached to the chest wall by suction or an adhesive. The amplified currents are recorded by either an Einthoven galvanometer or a cathode-ray oscillograph. Great care has to be taken to exclude extraneous noises. Though much good work has been done, there seems to be scope here for further work by physicists and electrical engineers in collaboration with medical colleagues.

METEOROLOGY. By P. A. SHEPPARD, B.Sc., F.Inst.P., Imperial College of Science and Technology, London.

THE CUMULONIMBUS AND THUNDERSTORM.

PART II : ELECTRICAL PHENOMENA.

5. THE BACKGROUND.

THERE is still no satisfying theory of the origin of thunderstorm electrification, though there is, as for long past, no lack of suggested sources of the separation of charge. It is well then to remind our-

selves at the outset that, if a theory is to satisfy, it must not only be consistent with the observed distribution of charge and field as to sense, level, etc., but must be able to account *at least as to order of magnitude* for the field strength and the *rate of charge separation*. Moreover, it must be consistent with, and indeed must build on, such knowledge as is available on the dynamics and physics (including microphysics) of cloud growth and decay. These properties of the cumulonimbus (Cb) have been discussed in Part I, but it may be useful to remind ourselves of some of them which seem to touch particularly on the generation of charge within cloud.

We note first then that the Cb consists of one or more cells, each of which goes through a fairly well-defined life cycle in an hour or two ; the earlier stages of the cycle are associated with updraughts, of appreciable horizontal and vertical extent, of order 10 m.sec.$^{-1}$, and the later (hail and rain) stages with downdraughts of the same order, with smaller upward motions persisting in parts to a late stage. *The Cb is then in its broad dynamical and physical aspects at the utmost remove from a steady-state phenomenon.* It is perhaps hardly necessary to remind the reader that, whether the air motion be upward or downward, precipitation elements will always *fall* with respect to the air and the smaller cloud elements, so that only the level or centre of gravity and not the nature of a charge separation process will be directly effected by the sense of the vertical motion. If, however, a change in sign of the vertical motion of the air leads ultimately to changes of phase or other physical properties of the cloud elements, charge separation processes may well be modified, destroyed or created.

As to the microphysics of the Cb, still not well explored, we are at least fairly certain of a few properties which are likely to be of great importance in any treatment of charge-separation processes. When the air motion is upward and the cell is developing, the cloud particles are almost certainly in the liquid phase at all levels, independent of temperature, except for a very few ice crystals at sub-zero temperatures. We must indeed regard the emergence of ice crystals at a rather advanced stage in the life cycle as the trigger for the production of precipitation from the cloud. Moreover, such precipitation as is observed could hardly occur unless the ice crystals remained relatively few until a quite advanced stage. For otherwise the cloud of supercooled water droplets would be quickly overseeded by an excess of centres of sublimation and the cloud would be almost as colloidally stable as in its earlier stages. In the final stages of the life-cycle there is in fact a very large production of ice crystals (the characteristic

anvil of the Cb is mainly composed of them) and their abundance is possibly related to the decay of the cell, through overseeding. Now a Cb becomes active electrically well before the cloud degenerates dynamically (*see* for example Workman and Reynolds' (1948) observations on single-cell Cb.) Consequently the charge separation must take place when ice crystals and other solid elements—graupel, etc.—are in quite weak admixture numerically, with the relatively abundant water droplets above the 0° C. level. Any process depending upon ice crystals alone or in relative abundance would only appear to be possible when the cell is decaying, electrically as well as dynamically. Finally, there is good reason to suppose that the production of precipitation elements follows very rapidly upon the emergence of a quite small number of centres of sublimation, through one or more chain reactions whose details remain to be determined.

6. The Distribution of Charge

With these dynamical and physical features as background we proceed to a consideration of the electrical phenomena themselves. We note first the strong evidence, furnished by several lines of investigation, that the Cb is essentially bi-polar with positive charge above negative, though with occasionally and perhaps often a strong local concentration of positive charge beneath the main region of negative charge and the 0° C. isotherm. The separation of the charge leading to the main dipole occurs, however, at sub-zero temperatures. The general level of the field within and below the active Cb is of the order of 100 v. cm.$^{-1}$ and only very locally does the field rise to the sparking limit two orders of magnitude greater.

7. The Charging of Cloud Elements

Findeisen (1940, 1942) has performed laboratory experiments upon the charge separation associated with changes of phase involving ice with the following results :

(i) Positive charge is acquired by an ice crystal growing from the vapour, the corresponding negative charge being carried away on ice splinters breaking from the parent crystal, as already discussed in another connection in Section 2 (Part I).

(ii) Negative charge, greater in rate of production and maximum amount than in (i), is acquired by an evaporating ice crystal or graupel, the separation again being associated with splinter formation. Findeisen attributes the difference in sign in this case to the development of facet forms

of crystal which do not apparently prevent splinter formation.

(iii) Positive charge, much greater in rate of production and maximum amount than in (i) or (ii), is acquired by a graupel or hailstone which rimes under bombardment from supercooled droplets, and splinter formation is again involved. The electrification ceases if glazed ice instead of rime occurs on the element.*
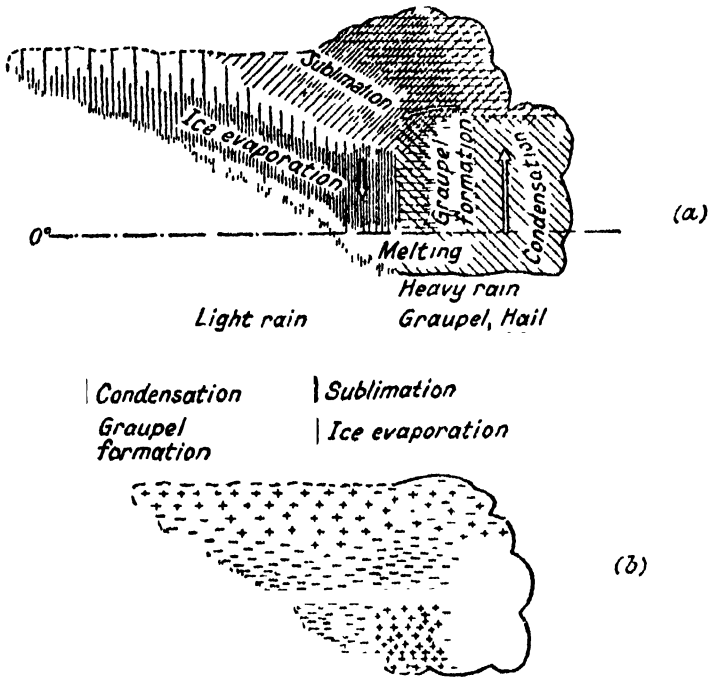
Fig. 4.—(a) The microphysical processes in a Cb, according to Findeisen. (b) The distribution of charge resulting, according to Findeisen, from charge separations involved with the ice phase.

Following these experiments Findeisen elaborated a picture of thundercloud structure which draws only on the above three processes for the generation of charge and which he considered would be consistent with the known electrical structure of the cloud. This picture is shown in the two parts of Fig. 4, and is qualitative

* This conclusion may need to be qualified if the rate of deposition of water is so rapid that the water which cannot be frozen streams off the glazing hail (see below).

only—a serious limitation. Even qualitatively, however, there are objections. Thus, the negative charge towards the base, ascribed to the evaporation of ice crystals, could only arise during cell decay. In the earlier, but still rather late, stage when numerous crystals are formed either by growth from nuclei or by splintering from riming graupels, the sense of charge separation is opposite to that required by the observed polarity of a Cb. Wichmann (1949) has elaborated Findeisen's picture without, however, adding greatly to its appeal. Moreover, recent experiments by Kramer (1948) have thrown some doubt on the validity of Findeisen's laboratory results. In a notoriously difficult field of work Kramer found that a riming graupel became positively charged during the initial period only and was followed by negative charging. He was also unable to detect negative charging during the evaporation of ice crystals.

Ross Gunn (1946) found that melting ice acquired substantial positive charge, the negative charge being carried away by bubbles of occluded air, liberated during evaporation. Thus melting snowflakes or hail would give rise to positive charge below the 0° C. level. This region has also been supposed by Simpson, following Lenard, to provide separation of the same sense due to the break-up of large raindrops. But Gill (1949) has shown that the sign of charge developed by breaking drops depends on the direction of the field, upwards or downwards, and the amount of the charge on the magnitude of the field—an instance perhaps of the Wilson influences mechanism in operation. There may perhaps be an analogue of this process at higher levels if hailstones shed (supercooled) water during the building up of their glazed ice shells. It is not, however, possible at present to assess the importance of any of these processes.

Observations on the charges carried by precipitation elements within cloud have been made by Ross Gunn (1947) in aircraft flights through Cb producing rain but not thunder. He found negatively charged elements only 1,000 ft. or more below the 0° C. level and positively charged elements only 8,000 ft. or more above that level, an admixture of signs occurring at intermediate levels. The number of such elements was about 400 m.$^{-3}$ and the average charge 0·05 e.s.u. Such volume charges are sufficient to account for the observed fields, allowing some volume charge of opposite sign to reside on the cloud particles proper. The distribution is also consistent with observed Cb polarity and with Scrase's (1938) observations on the electrification of rain at the surface from thunderless showers. The electrification of rain from thunderclouds is more complex, positive and negative drops occurring

together with almost equal frequency though the net charge may be systematically positive or negative over appreciable intervals of time. Ross Gunn (1949) finds that on average the charge q on a drop is related to its radius r by $q = 2.8r^2$ e.s.u. for $r > 0.3$ mm., independent of sign, while the maximum charge observed on a drop of radius r was $10r^2$ e.s.u., which corresponds to a field at its surface at which discharge will occur if the drop is distorted somewhat from the spherical. Simpson (1949) measured the net charge on rain in bulk and found that with the surface field numerically greater than 20 v. cm.$^{-1}$, with or without thunder, the sign of charge was opposite to that of the field (by convention a positive field is one which drives positive ions downwards). The rain current was proportional to the square of the field strength, i.e. to the natural point discharge current from surface objects, and Simpson considers that the rain derives its charge from this source of ions. In that case the sign of charge on precipitation elements aloft is not necessarily related directly to the sign of their charge at the ground—for the field near the ground may depend on other factors than the charge on precipitation elements aloft.

8. Frenkel's Theory of Cloud Electrification

J. Frenkel (1944, 1946, 1947) considers that the electrification of clouds arises primarily from the polar nature of the water molecule, which gives rise to a potential drop across the surface of a water droplet or ice crystal of 0.25 volt (Temkin, 1944). In an ionic atmosphere this results in a water droplet or ice crystal acquiring a negative charge q proportional to its radius r ($q \sim rV$ where $V = -0.25$ volt), leaving the air with a net positive charge. (The system is analogous to a colloidal electrolytic solution). Gravitational separation of the cloud particles then leads to a polar cloud with positive charge uppermost. If the gaseous or large ions were wholly deprived of mobility, i.e. fixed relative to the air, cloud particles would sink until their weight was balanced by the electric force produced by the polarisation of the cloud and the upper limit of field strength E in the cloud, assumed spherical, would be $4\pi gr^2/(3V)$, i.e. with $r = 10^{-3}$ cm., E $= 1200$ v. cm.$^{-1}$. In fact, the ions are mobile and the upper limit to the field strength is determined by the fact that in a steady state the convection current Nqv carried by the droplets (N = no. of droplets per unit volume, moving with velocity v with respect to the air) must equal the depolarisation current λE due to the ions, where λ is the specific conductivity of the air. With $r = 10^{-3}$ cm., $v = 0.3$ cm. sec.$^{-1}$, N $= 200$ cm.$^{-3}$ (corresponding to a water content of 1 gm. m.$^{-3}$),

and $\lambda = 2 \times 10^{-4}$ sec.$^{-1}$ (its value near the ground—it is probably lower in a cloud), $E = 100$ v. cm.$^{-1}$ which is of the observed order of magnitude in showery weather. As Simpson and his co-workers (1937, 1941) in their alto-electrograph flights showed, the higher field strength necessary for the initiation of a lightning flash must be quite localised, and this is due in Frenkel's view to precipitation elements which are unable to attain their equilibrium charge, $- 0 25r$, on account of a high rate of absorption of charge by collision with the cloud droplets. This high rate of charging is considered to lead to electrical breakdown at the surface of the precipitation elements and we have already seen that Ross Gunn has observed charges bordering on this limit.

It will be noted that the above argument applies to all clouds. The Cb, however, which is characterised by larger water contents than other clouds, is capable of generating a greater field, since for a given conductivity the field is proportional to Nqv, which in turn is roughly proportional to the mass of water per unit volume (accurately so if the droplets obey Stokes' Law). There are of course other differences than field strength between Cb and other clouds —*see*, for some of these differences, Simpson (1949). Here we note only that the point discharge current which sets in at surface excrescences in high fields is capable of modifying appreciably some of the electrical phenomena to be observed at the surface.

Again, the argument presented above takes no account of the Wilson influence mechanism which operates to charge a drop in an ionised atmosphere in a sense opposite to the field through which it falls. Frenkel argues that the influence mechanism does not affect the essential charge separation process, though it may be important in explaining some aspects of precipitation electricity. Moreover, Frenkel disputes that the influence mechanism has the effect commonly supposed and for which Gott provided some, though not conclusive, experimental evidence. He argues that the sign of charge is that of the greater polar conductivity, *viz.* λ_+, of the positive ions, the amount of charge being approximately $\dfrac{\lambda_+ - \lambda_-}{\lambda_+ + \lambda_-} r^2 E$. For r sufficiently small this charge decreases insignificantly the " fundamental " negative charge rV, but grows in importance with r until at $r = 0.2$ mm. (a small raindrop) it destroys the negative charge in a field of 100 v. cm.$^{-1}$ for $\lambda_+/\lambda_- = 1.3$ (Frenkel gives the necessary field under the assumed r and λ_+/λ_- as 1 v. cm.$^{-1}$, presumably an arithmetical error, but an important one, as the lower value would affect the sign of light and moderate steady rain, during which the field is normally only a few volts

per cm., whereas the higher value would imply that rain falling in a steady small field should always be negative—it is overwhelmingly positive). Frenkel objects to the Wilson influence mechanism because a drop carries the air in its immediate neighbourhood with it by viscous action and so he considers that gravitational fall cannot give rise to selective absorption of the ions. We note, however, that the carriage of air is only partial. Whipple and Chalmers (1944) computed the absorption under various assumptions, including the case of viscous flow (Stokes' Law for a sphere) and obtained a final charge of order $-r^2E$ in most cases, but zero charge, or of the same sign as E or as the initial charge, in others. It cannot yet be said that even the semi-quantitative operation of the influence mechanism as it applies to conditions in and below Cb is known, or even whether it is important within the cloud, where ice as well as water has to be considered (*see* Chalmers, 1947). But it is unquestionably important, if not yet fully resolved, in regard to the precipitation reaching the ground. In the simpler case of quiet rain from stratiform cloud there is still much difficulty, for, whereas Whipple and Chalmers obtain a charge per drop of about $- 0.5Er^2$ e.s.u. for these conditions, it may be inferred from the observations of Simpson (1949) that the charge is then in fact given by $- 18(E - 0.013)r^3$ e.s.u.—it is perhaps a matter for congratulation at this stage that the same two variables only are involved in each expression !

We have digressed rather from our discussion of Frenkel's theory in following up the effects of the influence mechanism, and in concluding this article would re-direct attention to that theory. Frenkel has argued the matter very closely in his first two papers and we have certainly not done it justice in the summary given above. Some parts of his argument are obscure, and some of his conclusions uncertain, in a numerical sense, on account of uncertainty in the magnitudes of some of the critical parameters. But the theory has been worked out *in extenso*, *e.g.* in regard to the rates of the various processes, and difficulties are faced. It is unlikely to be final—that almost certainly must wait on further knowledge of Cb microphysics generally—but it is a theory which merits greater attention than it has so far received in the literature of the subject.

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ORGANIC CHEMISTRY. By A. W. JOHNSON, M.A., Ph.D., A.R C.S., University Chemical Laboratory, Cambridge.

ANTI-ARTHRITIC COMPOUNDS.—The last year has witnessed an enormous publicity given to certain organic compounds which have been applied successfully in the treatment of arthritis and other rheumatic complaints, and the latest indications are that they will be also beneficial in several other diseases. The economic production of these substances presents a major challenge to present-day organic chemists and biochemists, and a tremendous effort is being put into this field both in academic and industrial laboratories, so there is no doubt that the next few months will witness many spectacular advances in this subject. Any review of the work at the present time must therefore be regarded only as an interim report.

(I)   (II)
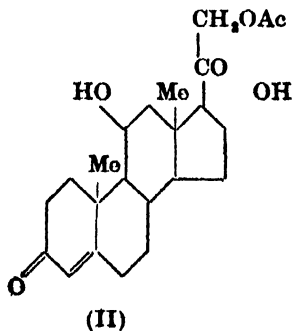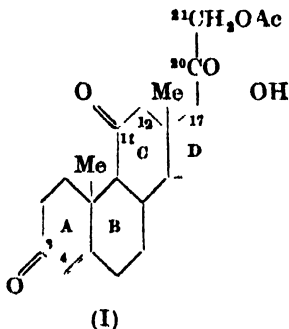
Much of the chemical work so far carried out has concerned certain steroids, in particular cortisone (I), the monoacetate of

11-dehydro-17-hydroxycorticosterone, compound E, which is one of the group of adrenal cortical hormones.

Besides cortisone a few other compounds have been reported to show similar activity. In the steroid group, the monoacetate (II) of 17-hydroxycorticosterone, compound F, is active, although it is more difficult to obtain than cortisone. Activity has been claimed for the acetate (III) of 11-desoxy-17-hydroxycorticosterone, substance S; the combination of the acetate (IV; " Doca ") of 11-desoxycorticosterone with ascorbic acid (*Lancet*, 1949, **257**, 993); Δ^5-pregnen-3β-ol-20-one (v), and the monoacetate (vi; " Artisone ") of Δ^5-pregnene-3:21-diol-20-one (*Chem. Eng. News*, 1950, **28**, 552) although these claims are still largely unsubstantiated.
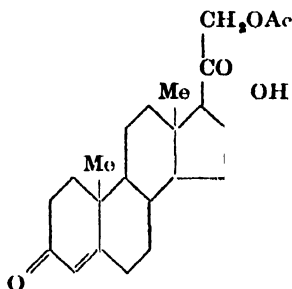
(III)
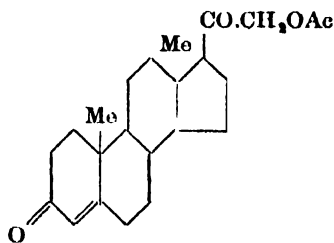
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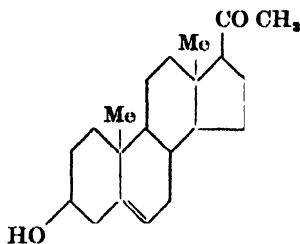
(V)
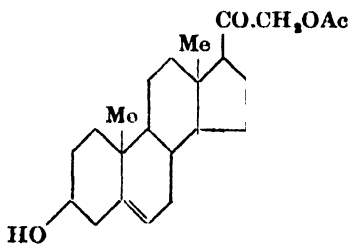
(VI)

Of outstanding importance in the non-steroid anti-arthritic compounds is the adrenocorticotropic hormone (ACTH), which is a protein isolated from pituitary glands and which stimulates the production of several adrenal hormones. This compound is discussed in more detail at a later stage. *mally* glucurone (probably vii), the lactone of glucuronic acid, has been claimed to be effective

in about 60 per cent. of the cases tested, depending on the type and cause of the arthritic condition (*Chem. Eng. News*, 1950, **28**, 44).

(VII)
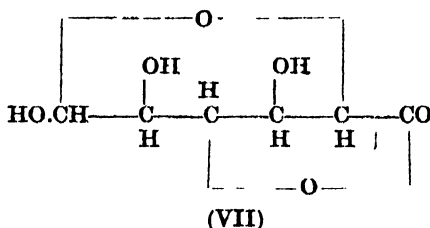
Cortisone.—Compound E is one of the twenty-eight crystalline substances isolated from the adrenal cortex and was first isolated in 1936 in three different laboratories. Wintersteiner and Pfiffner (*J. biol. Chem.*, 1936, **114**, lxxx ; **116**, 291) designated the product " substance F " ; Reichstein (*Helv. chim. Acta*, 1936, **19**, 1107) named it " substance F_a " and Mason, Myers and Kendall (*J. biol. Chem.*, 1936, **114**, lvii, 613 ; **116**, 267) called the substance " compound E," by which name it is commonly known today. Steiger and Reichstein (*Helv. chim. Acta*, 1937, **20**, 817, 953) showed the three compounds to be identical and to have the structure (I ; —OH group at C_{21}). For several years compound E along with the other cortical hormones was available only in very limited amounts, but the discovery of alternative sources, particularly partial syntheses from more readily available materials, enabled a fuller evaluation of its physical properties to be made and led to the dramatic announcement of the successful application of cortisone in the treatment of arthritis (Hench, Kendall, Slocumb, Polley *et al*, *Proc. Staff Meet. Mayo Clinic*, 1949, **24**, 181, 277). The necessary dose of cortisone required for relief is some 100 mg. daily and the total amount of the drug required is thus very substantial—it is estimated that there are seven million arthritis patients in the United States alone. There is, however, preliminary evidence that the administration of these relatively large quantities of adrenal hormones may bring about secondary disorders, similar for example to Cushing's syndrome, but full information on this point is still awaited.

As the preparation of compound E in large quantities from adrenals is quite impracticable, most of the work on this substance has been concerned with its production either from alternative sources or by partial synthesis. It has been known for some time that in normal urine there is present a large variety of keto-steroids (*e.g.* Fieser and Fieser, *Natural Products Related to Phenanthrene*, New York, 1949, p. 490 ; Liebermann, Dobriner *et al.*, *J. biol. Chem.*,

1946, **166**, 773 ; 1948, **172**, 263 ; 1950, **182**, 299) including several 11-oxygenated steroids, and quite recently (*Science*, 1950, **111**, 61 ; *J. biol. Chem.*, 1950, **183**, 365) Scheider has reported the isolation of compound E from normal male urine (32 mg. from 1000 l.). It has also been found that compound F (II, —OH group at C_{21}) can be isolated from the urine in a case of Cushing's syndrome (191 mg. from a 25-day collection) (Mason and Sprague, *J. biol. Chem.*, 1948, **175**, 451) and probably also from the urine of patients who had undergone major surgical operations or who had been treated with cortisone (Mason, *ibid.*, 1950, **182**, 131).

A further important recent observation is the realisation of direct bio-oxygenation of steroids in the 11-β-position by perfusion through isolated adrenal glands (Hechter, Jacobsen, Jeanloz, Levy, Marshall, Pincus and Schenker, *J. Amer. Chem. Soc.*, 1949, **71**, 3261 ; *Arch. Biochem.*, 1950, **25**, 457). Oxidations of 11-desoxycorticosterone acetate (IV), 11-desoxy-17-hydroxycorticosterone acetate (III) and androsterone and further similar reactions are in progress.

The main difficulties of any partial synthesis of cortisone are the introduction of the oxygen atom at C_{11} and the building up of the ketol side-chain. These will be considered in turn, but the methods available for overcoming these formidable obstacles unfortunately involve many stages and the yields of the final products are very small. The overall yield of cortisone in the 37-step process from deoxycholic acid, as worked out by Sarett and which is the preferred source at present, is of the order of 0·05 per cent. With regard to the C_{11} oxygen atom, the available chemical methods for its introduction have been summarised by Fieser and Fieser (*loc. cit.*, p. 452) and by Reichstein (*Chimia*, 1950, **4**, 21, 47) and require as starting material a steroid either with an oxygenated substituent at C_{11} or C_{12} or an unsaturated linkage at $C_{11\,12}$. Thus, as there are very few C_{11} oxygenated steroids which occur naturally, the most common starting products are the bile acids containing a hydroxyl group at C_{12}, *e.g.* deoxycholic acid (VIII) from ox bile.

(VIII)   (IX)
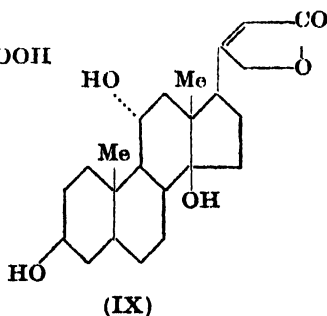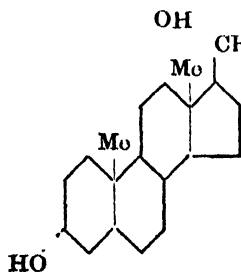
The conversion of the C_{12} hydroxy-, or the Δ^{11} unsaturated steroids formed from them by dehydration or through the C_{12} acyloxy compounds, to 11-ketosteroids may be carried out as follows. Full details will be found in the original references.

(i) Lardon and Reichstein, *Helv. chim. Acta*, 1943, **26**, 747 and later papers :

OH
Me

C

$\longrightarrow$

HOBr
$\longrightarrow$

HO Br

CrO₃

Br
O

Zn/HOAc
$\longrightarrow$

O
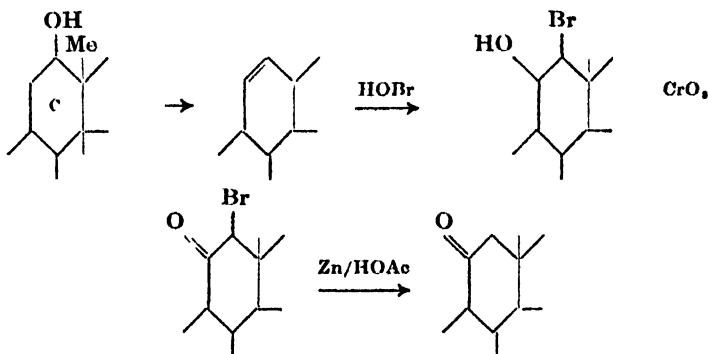
(ii) Gallagher *et al.*, *J. biol. Chem.*, 1946, **162**, 495–549 :

O

C

Br₂
$\longrightarrow$

Br O

KOH
$\longrightarrow$

HO O

$\longrightarrow$

(2 isomers)

(2 isomers)

O OH

PBr³
$\longrightarrow$

O Br

Zn/KOH
$\longrightarrow$

O
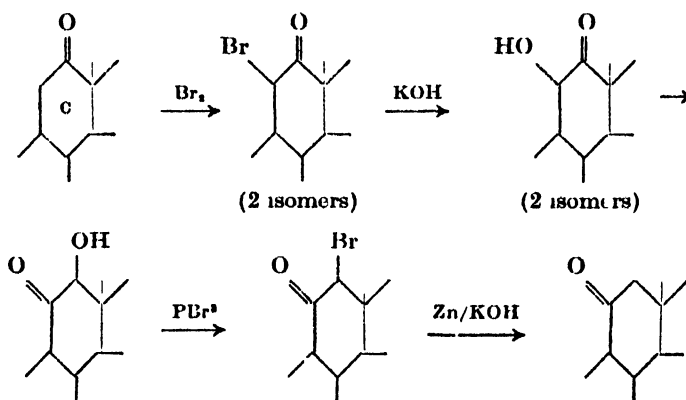
(iii) McKenzie, Mattox, Engel, Kendall *et al.*, *ibid.*, 1946, **162**, 565, 571 ; **164**, 569 ; **166**, 345 ; 1948, **173**, 271 ; **175**, 249 :

O

Me C

HO

SeO₂

O

H₂

OH
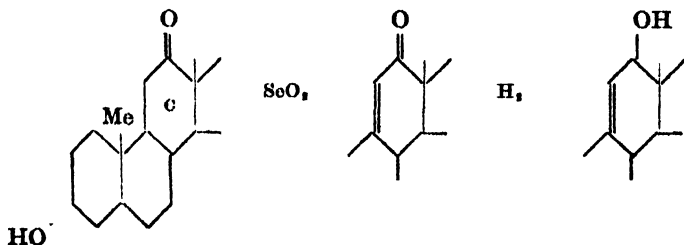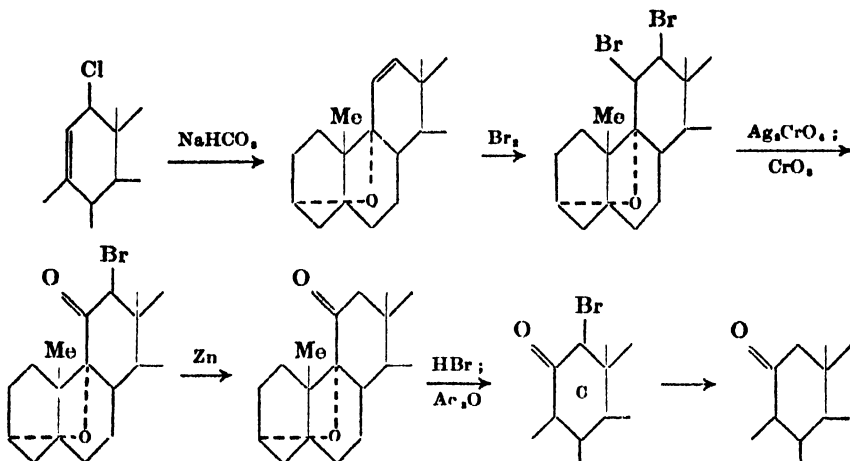
Any steroid already oxygenated at C_{11} is thus worthy of very careful consideration as a possible starting material for cortisone. Such compounds are rare and sarmentogenin (IX, a heart poison which occurs in the South African plant *Strophanthus sarmentosus*, is an outstanding case (Katz, *Helv. chim. Acta*, 1948, **31**, 993). There appears, however, to be some confusion in the systematics of the genus *Strophanthus* (Reichstein, *Chimia*, loc. cit.) and expeditions have been sent to Africa to assess various species. It has been repeatedly emphasised that even if a suitable source of sarmentogenin is found, the production of this tropical plant on a large scale must of necessity be a long-term proposition. Another C_{11} oxygenated steroid, gamabufotalin, has been described recently and has been assigned the structure (X) (Meyer, *Helv. chim. Acta*, 1949, **32**, 1599). It is obtained from the skins of certain Chinese and Japanese toads (35 g. from 5000 skins) and is unlikely to be available in quantities sufficient to meet the demands for cortisone.

Marker (*Chem. Eng. News*, 1949, **27**, 3348 ; *J. Amer. Chem. Soc.*, 1949, **71**, 2656) has made a study of the various steroidal saponins which are oxygenated in the C_{12} position, and botogenin (XI) may be taken as a typical example of the eight cases described. These sapogenins are converted to pseudosapogenins with acetic anhydride and the latter are oxidised with chromic acid to derivatives of 5:16-pregnadien-3-ol-12:20-dione (*e.g.* XII). However, from the point of view of early supplies of cortisone, a caution against over-optimism regarding these saponins as raw materials has been given by Williams (*Chem. Eng. News*, 1949, **27**, 3516), even granting that in many cases the plants are non-tropical and the saponin content is relatively high (up to 10 kg./ton of plant).

(X)

(XI)

Ac₂O , CrO₃

(XII)

(XIII)
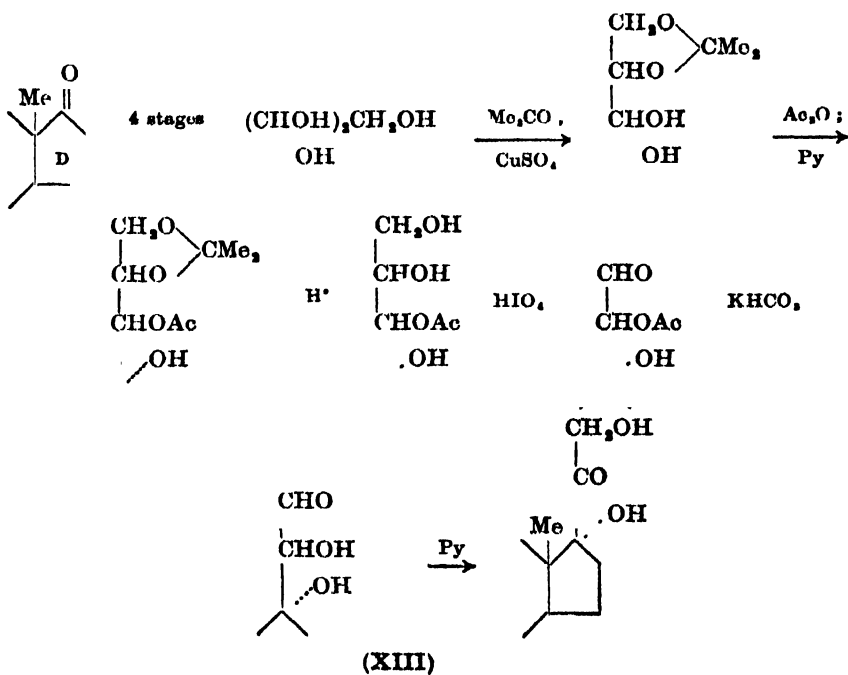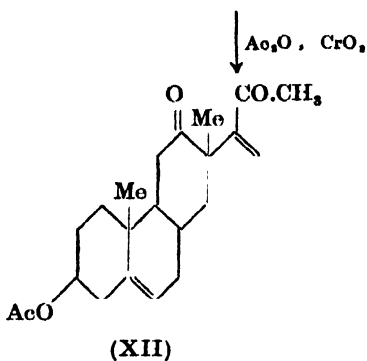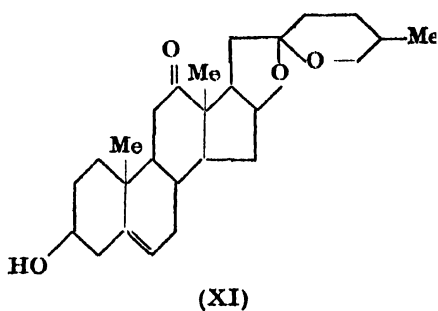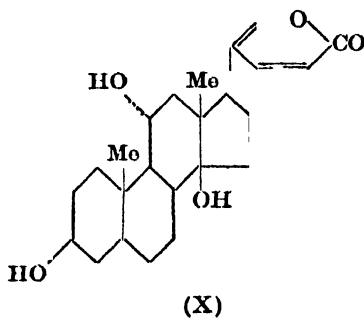
The second major problem in any synthetic approach to cortisone is the building up of the carbon side-chain on C_{17}. A number of methods have been described for this, the earlier routes comprising the degradation of the sterol or bile acid to a C_{17} ketone followed by the re-addition of two carbon atoms and the later methods largely being transformations of the pregnane ketones. The original method of Reichstein and von Euw (*Helv. chim. Acta*, 1940, **23**, 1114, 1258) was as follows, the intermediate (XIII) having previously been described by Butenandt and Peters (*Ber.*, 1938, **71**, 2688).

Space does not permit the full detail of these various methods of building up the side-chain at C_{17} and the formulae given are concerned only with the reactions of the side-chain. Other reactions are often necessary to introduce the keto group at C_3 or the Δ^4-double bond and the originals must be consulted for the complete syntheses

(i) Sarett, *J. biol. Chem.*, 1946, **162**, 601 :

CH₂OH structures omitted
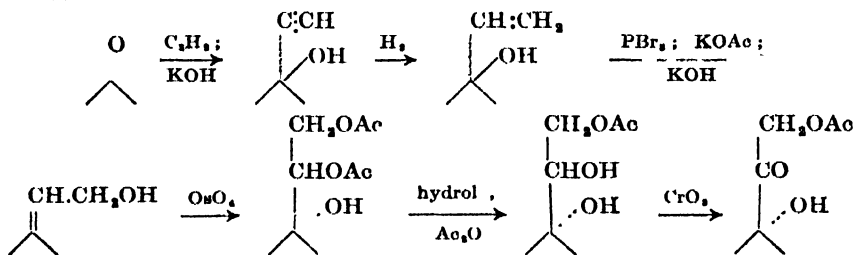
(ii) Sarett, *J. Amer. Chem. Soc.*, 1948, **70**, 1454   1949, **71**, 2443 :
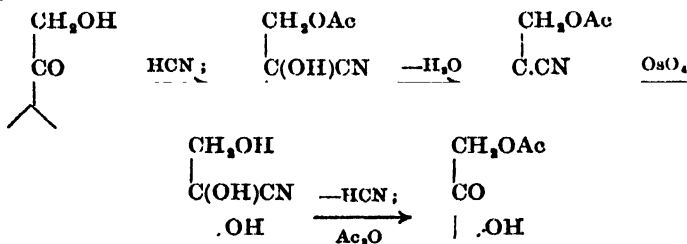
(iii) Koechlin, Garmaise, Kritchevsky and Gallagher, *ibid.*, 1949, **71**, 3262 :
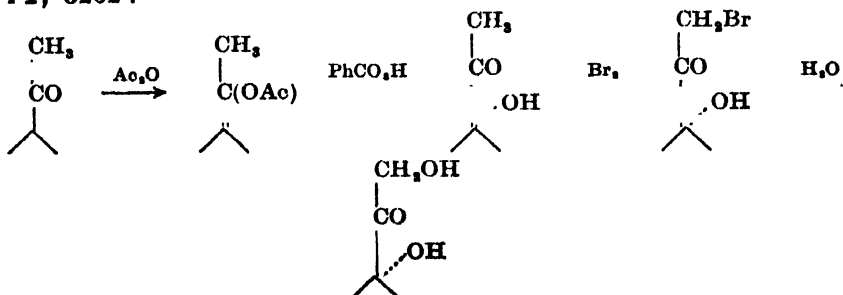
(iv) Wagner and Moore, *J. Amer. Chem. Soc.*, 1949, **71**, 4160 :

CH$_3$
CO   Br$_2$
(A)

CHBr$_2$
CO
Br $\xrightarrow{\text{KOH}}$ $\overset{}{\text{HCl}}$

COOH
CBr
(A)

CH$_2$N$_2$;
$\overset{}{\text{LiAlH}_4}$

CH$_2$OH
CBr
(A) $\xrightarrow[\text{OsO}_4]{\text{Ac}_2\text{O}}$

CH$_2$OAc
CO
.OH
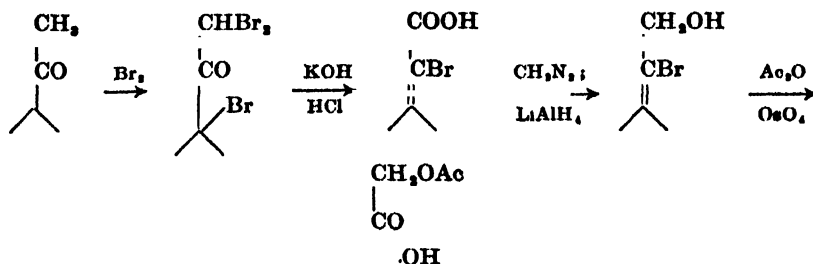
(v) Julian, Meyer, Karpel and Ryden, *ibid.*, 1949, **71**, 756, 3574 :

CH$_3$
CO $\xrightarrow{\text{PhCO}_3\text{H}}$

CH$_3$
CO
O
CH$_2$OAc
CO
O $\xrightarrow[\text{Br}_2]{\text{Br}_2 , \text{HBr} ,}$

CH$_2$Br
CO
OH
Br
CH$_2$OAc
CO
OH $\xrightarrow[\text{NaI , KOAc}]{\text{HBr/MeOH ;}}$

HBr ,
Raney Ni
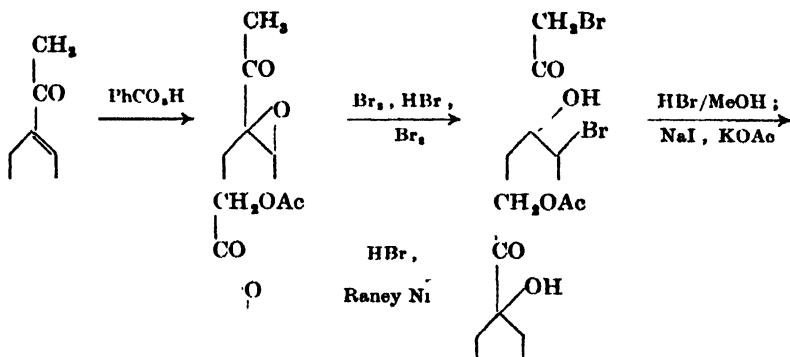
It will be obvious from the above that at the present time there is no convenient source of cortisone and that the methods of partial synthesis are difficult, involving many stages with consequent low yields. It is probable that other methods of production remain to be discovered, *e.g.* a microbiological source would be especially attractive ; furthermore it is possible that the cortisone molecule will be simplified in such a manner that the biological activity is preserved and the adverse secondary effects are diminished. It may be also that the preferred agent will not be a steroid, and indeed a most promising approach to the solution of the arthritis problem lies in the adrenocorticotropic hormone (ACTH), the early work on which has been reviewed by Li and Evans (*Vitamins and Hormones*, New York, 1947, **5**, 197). ACTH was first isolated from the pituitaries of sheep (Li, Evans and Simpson, *J. biol. Chem.*, 1943, **149**, 413) or pigs (Sayers, White and Long, *ibid.*, 1943, **149**, 425 ; Fishman, *ibid.*, 1947, **167**, 425). The stimulating influence of the pituitary on the function of the adrenal cortex has been known for

many years and more recently it has been shown that in humans this stimulation is accompanied by increased excretion of 11-oxygenated steroids. In 1949 it was announced that ACTH was active against rheumatoid arthritis (Hench, Kendall, Slocumb and Polley, *Proc. Staff Meet., Mayo Clinic*, 1949, **24**, 181) and other physiological properties of ACTH have also been described (*Chem. Eng. News*, 1949, **27**, 3305 ; *Lancet*, 1950, **258**, 169). The hormone is a protein of molecular weight about 20,000, but Li (*1st Internat. Congr. Biochem.*, 1949, *Abs. of Communications*, p. 386) has reported that it retains its potency, in rats, after partial hydrolysis with pepsin or acid. Thus the hormonal activity resides in the hydrolysed fragments of the original protein molecule, and it was estimated that these fragments contained an average of seven or eight amino acids. It has since been demonstrated (*see also* Brink, Meisinger and Folkers, *J. Amer. Chem. Soc.*, 1950, **72**, 1040) that such pepsin digests of ACTH are active in cases of rheumatoid arthritis. Other methods of preparing potent adrenocorticotropic preparations depending on methods of extraction and ultra-filtration have been described (Curtis-Jones, Crooke, Henley, Morris and Morris, *Biochem. J.*, 1950, **46**, 173 ; Morris and Morris, *Lancet*, 1950, **258**, 117). It is probable that the established methods of peptide analysis will enable the structure of the active fragments of the ACTH molecule to be determined and there is also the possibility of the synthetic approach to these molecules. Meanwhile the production of ACTH is still very small and the isolation procedure is lengthy, so that the clinical evaluation of the substance is still largely experimental, but the solution to the cortisone problem may well come from the further studies on ACTH.

BIOCHEMISTRY. By C. LONG, M.A., B.Sc., D.Phil., Department of Biological Chemistry, University of Aberdeen.

RECENT STUDIES ON PHOSPHOLIPINS
(*continued from* SCIENCE PROGRESS, No. 150, April 1950)

THE ACTION OF ENZYMES ON PHOSPHOLIPINS

MANY publications dealing with the enzymatic hydrolysis of phospholipins in animal tissues have been in the nature of autolysis studies. Only occasionally have cell-free tissue extracts been used and in these lecithin has generally been employed as substrate ; however, there is reason to believe that in some of these cases, essentially similar results would have been obtained with phosphatidyl ethanolamine. In a single reported instance, which will

be mentioned later, sphingomyelin was found to be split by a bacterial enzyme. The literature contains much confusing nomenclature regarding these enzymes ; in the following discussion, however, they will be referred to as *phospholipases*.

First, it is desirable to refer briefly to the fate of dietary phospholipins in the alimentary tract. The assumption has generally been made that a certain degree of hydrolysis takes place before absorption. Quite recently, Le Breton and Pantaléon (*Arch. Sci. physiol.*, 1947, **1**, 63) have provided support for this assumption by showing that dog pancreatic juice was able to split off the two fatty acid radicals from purified lecithin. However, it is almost certain that much of the dietary phospholipin is absorbed intact, for Artom and Swanson (*J. biol. Chem.*, 1948, **175**, 871) have observed that, after oral administration to rats of mixed phospholipins containing the radioactive isotope of phosphorus, P^{32}, the specific activity of the liver phospholipin-P^{32} was much greater than following a mixture of radioactive inorganic phosphate and non-radioactive phospholipin.

By contrast with the phospholipases of pancreatic juice, the intracellular enzymes are often extremely active in the decomposition of tissue phospholipins. A number of cases may be cited in which this general breakdown has been studied. Fairbairn (*J. biol. Chem.*, 1945, **157**, 645) examined whole mouse tissue and cat-liver for free fatty acids immediately after the death of the animal and found the amount to be extremely small. A few minutes after the removal of the liver from an animal, however, the constituent phospholipins were observed to undergo hydrolysis by intracellular phospholipases. The rate of decomposition was relatively slow in the intact tissue, but took place much more rapidly when the liver was ground and incubated. The liberation of fatty acids was closely paralleled by the formation of free choline and inorganic phosphate. From this it may be inferred that an armoury of enzymes is present in liver tissue, capable of bringing about the complete hydrolysis of a lecithin molecule.

A rather similar series of investigations has been undertaken by Kahane and Levy (*Bull. Soc. Chim. biol.*, 1945, **27**, 544, 588 ; *Helv. Chim. Acta*, 1946, **29**, 1322) who have examined the effects of autolysis in homogenates of rat tissues. In general they found that the phospholipins suffered only partial breakdown to give intermediate products which could be isolated, but they also observed more complete destruction in some of the cases studied. Thus, tissue extracts prepared immediately after the death of the animal contained only small amounts of free choline, whereas if the extracts

were prepared several hours after death the quantity was greatly increased.

The widespread occurrence of phospholipases has recently been amply confirmed by Režek (*Enzymologia*, 1946–48, **12**, 59) who has found them to be active in the hepatopancreatic juice of *Helix pomatia*. Added lecithin was split into fatty acids, glycerol, inorganic phosphate and choline. In the early stages of the reaction, fatty acids and glycerophosphorylcholine were the main products, but later this diester was almost completely broken down to glycerol, inorganic phosphate and choline.

These examples show that there is no lack of phospholipases in animal tissue and indeed this fact is the main cause of the difficulty of separating the various enzymes from one another and of studying them independently. The problem has to some extent been overcome, but only by making use of the phospholipases from plant, bacterial and other sources, where the enzymes often occur singly. These individual phospholipases will now be considered in turn.

The partial hydrolysis of certain phospholipins to yield lyso-phospholipins and one molecule of fatty acid is caused by an enzyme found in the venom of certain snakes. The lysophospholipins are well-known hæmolytic agents and the lethal effects following snake-bite are mainly due to this enzyme. It may be supposed to act *in vivo* upon the tissue phospholipins to form lysophospholipins which pass into the blood and lake the cells. Chargaff and Cohen (*J. biol. Chem.*, 1939, **129**, 619) have shown that the enzyme from cobra venom acts upon purified lecithin but not upon a purified brain kephalin, but both lecithin and kephalin in crude egg-yolk phospholipin were found to be attacked. Since the complex nature of brain kephalin was unknown in 1939, the experiments of Chargaff and Cohen with purified kephalin should be treated with some reserve. Fairbairn (*J. biol. Chem.*, 1945, **157**, 633), using the moccasin enzyme, found that both lecithin and kephalin in crude ox-brain phospholipins could serve as substrate and also confirmed a previous finding, namely that the enzyme liberates only un-saturated fatty acids of high iodine value. Chargaff and Cohen found the resulting lysophospholipins to contain no unsaturated groups. The enzyme obtained from the venom of *Crotalus terrificus* has been crystallised by Slotta and Fraenkel-Conrat (*Ber.*, 1938, **71B**, 1076) and is called by them *crotoxin*.

A similar phospholipase has been extracted from horse pancreas by Ogawa (*J. Biochem. (Japan)*, 1936, **24**, 389) and by Belfanti and Arnaudi (*Boll. Soc. intern. Microbiol., Sez. ital.*, 1932, **4**, 399).

However, it is probable that, under physiological conditions in the pancreas, the lysophospholipins are further broken down as fast as they are formed.

The liberation of the second, *i.e.* saturated, fatty acid from lysophospholipins is caused by lysophospholipase, an enzyme which has been isolated by Fairbairn (*J. biol. Chem.*, 1948, **173**, 705) from culture media in which *Penicillium notatum* had been grown. The other product of the reaction, which incidentally has no hæmolytic properties, is glycerophosphorylcholine or glycerophosphorylethanolamine, depending on whether the lysophospholipin was originally derived from lecithin or phosphatidyl ethanolamine. The enzyme was found to be quite specific for lysophospholipins, the breakdown of which did not proceed beyond the diester stage, for no free choline or inorganic phosphate were formed.

Many other studies have been reported in which glycerophosphorylcholine has been formed enzymatically from lecithin, presumably by the combined action of enzymes similar to those just described. Thus Contardi and Ercoli (*Gazz. chim. ital.*, 1933, **63**, 37) observed this breakdown using enzyme extracts prepared from rice grain or *Aspergillus oryzæ*. Again, Schmidt, Herschman and Thannhäuser (*J. biol. Chem.*, 1945, **161**, 523) found that, when various rat tissues or ox-pancreas were minced and incubated at body temperature, the loss of lipide-phosphorus was paralleled by the formation of the acid-soluble glycerophosphorylcholine. It was assumed to have been formed from the tissue lecithin. Of considerable importance is the finding that the product isolated in this investigation was the optically-active L-α-glycerophosphorylcholine.

The breakdown of glycerophosphorylcholine by the enzyme cholineglycerophosphatase, although of widespread occurrence in animal tissues, has not been fully investigated. Contardi and Ercoli (*Arch Sci. biol.*, 1935, **21**, 1) state that the enzyme is absent from extracts of unripe rice although present in the mature grains. Kahane and Levy (*Bull. Soc. Chim. biol.*, 1945, **27**, 354) showed the presence of the enzyme in rat-prostate extract and that its action was to split the molecule at the choline-phosphate ester linkage, thus forming glycerophosphate and releasing free choline.

The enzymatic loss of choline from lecithin has only been observed in plant cells. It will be recalled that Chibnall and Channon (*Biochem. J.*, 1927, **21**, 233, 1112) had earlier isolated a simple phosphatidic acid from minced raw cabbage. In a recent series of papers, Hanahan and Chaikoff (*J. biol. Chem.*, 1947, **168**, 233; **169**, 699; 1948, **172**, 191) showed that, when cabbage or carrots were steamed, subsequent extraction with lipide solvents yielded a

mixture of phospholipins containing choline; when, however, similar extraction methods were applied to raw carrots, a phosphatidic acid, free from choline, and believed to be similar to the substance isolated by Chibnall and Channon, was obtained. The enzyme responsible for this hydrolysis has been isolated by Hanahan and Chaikoff from both raw carrots and cabbage and has been found to liberate choline from purified lecithin and to form the corresponding phosphatidic acid.

Hydrolysis of lecithin into phosphorylcholine and a diglyceride has been shown by Macfarlane and Knight (*Biochem. J.*, 1941, **35**, 884) to be caused by an enzyme present in culture filtrates from *Clostridium welchii* (Type A). This enzyme is almost certainly identical with the α-toxin, a hæmolytic, lethal substance secreted into the medium by this organism during growth. Its activity is specifically inhibited by Type A *Clostridium welchii* antitoxic sera. The mechanism of this hæmolytic effect probably involves the destruction of the lecithin present in the cell-wall of the red blood corpuscle. Such an action is quite different from the effect produced by lysophospholipins which are hæmolytic *per se*. Later work by Macfarlane (*Biochem. J.*, 1948, **42**, 587, 590) has shown that the same enzyme will also split phosphorylcholine from sphingomyelin, although more slowly than from lecithin. Apart from this, its action is very specific, for it will not attack phosphatidyl ethanolamine, phosphatidyl serine, lysolecithin or glycerophosphorylcholine.

Finally, it remains to mention briefly the enzymatic hydrolysis of the two phosphate esters encountered, glycerophosphoric acid and phosphorylcholine. These compounds are very similar in two respects. They are both very resistant to acid hydrolysis, being broken down only by prolonged boiling with fairly concentrated mineral acids, and they are rapidly hydrolysed by the acid and alkaline phosphatases present in nearly all animal tissues. Of some interest is the recent report by Lundquist (*Nature*, 1946, **158**, 710 ; *Acta physiol. Scand.*, 1947, **14**, 263) that phosphorylcholine occurs in relatively high concentration in fresh seminal fluid and that on allowing to remain at room temperature acid phosphatase, which is also present in high concentration, decomposes it into inorganic phosphate and choline.

GEOLOGY. By G. W. Tyrrell, A.R.C.Sc., D.Sc., F.R.S.E., The University, Glasgow.

Metamorphism and Metamorphic Rocks.—In his Presidential Anniversary Address to the Geological Society, H. H. Read (*Quart. Journ. Geol. Soc.*, CIV, 1948, 155–205) examines such notions as

zones, facies, assemblages, and fronts, mainly from the spatial aspect. While a correlation of metamorphic zones and facies is possible, Professor Read does not think the facies concept has any value in the interpretation of metamorphic history. In regard to locus in depth he distinguishes between true or geosynclinal depth, tectonic depth, and " magmatic-migmatic " depth, and concludes that the last-named is of the greatest significance in metamorphism. Harker's division of metamorphic minerals into stress and anti-stress groups is thought to be of little significance.

It is suggested that tangential drag due to convection currents is of more significance in metamorphism than orogenic compression. In most metamorphic rocks banding is bedding, but in the deep Archæan there may be processes of metamorphic diffusion and differentiation which may lead to banding. Regional metamorphism most likely results from the passage of waves (fronts) of metasomatising solutions out from the central cores of granitisation about which arise the metamorphic zones. Incidentally Professor Read dismisses cataclasis from the general definition of metamorphism and merges contact metamorphism in regional metamorphism. We may wonder where these poor orphans of the metamorphic storm, valid enough in their numerous products, can find a place in classification.

In his paper " On Lineation and Petrofabric Structure, and the Shearing Movement by which they have been produced," E. M. Anderson (*Quart. Journ. Geol. Soc.*, CIV, 1948, 99–132) regards the arguments for the current view that lineation is perpendicular to the direction of shearing or " transport " as unconvincing. He prefers the contrary view that lineation is parallel to the shearing movement as inherently more probable, especially on the basis of the Norwegian evidence, and on the evidence afforded by elongation of pebbles in distorted conglomerates. If this conclusion is accepted it will necessitate a revision of present ideas of petrofabric structure, and especially about the formation of single quartz and mica girdles. The direction of shearing or " transport," in fact, must be normal, not parallel, to the plane of the girdles.

R. A. Sonder discusses the results of experiments made by the Swiss Institute for Testing Materials on the elastic anisotropy of crystalline schists, and deals with the problems of fabric orientation, schistosity and deformation of rocks, in his paper on " Gefüge-regelung, Druckschieferung, und Druckverformung von Gesteinen " (*Schweiz. Min. Petr. Mitt.*, XXVIII, 1948, 362–79). So far the experiments have confirmed Sonder's theoretical view that the elastic axes of crystals with the lowest Young's modulus will tend to

orientate themselves parallel to the stress axis during movements and recrystallisation. Further, the older view that pressure makes rocks " plastic " is not confirmed, as extreme pressures seem to be unable to make crystals plastic. Rock deformation is possible only by crushing with intergranular movements in the presence of a liquid phase, at least in the upper parts of the crust. The order of magnitude of stresses in mountain-making may be as much as 10,000 atmospheres. These points make the well-known shear theory of orientated fabrics and schistosity somewhat doubtful.

Discussing " Lineation in Moinian and Lewisian Rocks of the Northern Highlands of Scotland," F. C. Phillips (*Geol. Mag.*, LXXXVI, 1949, 279–87) criticises recent statements that, in the Moine Schists, the south-easterly plunging lineation appears to increase in intensity as the Moine Thrust area is approached, as these statements are not, in his view, in accordance with field observations. At any rate they afford only a precarious basis for the conclusion that thrusting and lineation are related. Furthermore, a vital fact in relation to this question is the widespread development of a similar lineation, plunging to the south-east, and likewise expressive of a girdle fabric, in the unmoved Lewisian rocks of the foreland.

J. E. Richey describes the " Pre-Metamorphism Cleavage in the Moine Schists of Morar, Western Inverness-shire " (*Trans. Edin. Geol. Soc.*, XIV, Pt. II, 1948, 200–19). The rocks affected are highly-inclined, thin, alternating beds of psammitic and pelitic schists. Miniature drag-folds have produced low, closely-spaced, parallel ridges on the bedding planes of some psammitic layers, which have a striking resemblance to ripple-marks. Thin sections, however, show structures interpreted as slaty cleavage crossed by strain-slip or fracture cleavage. These cleavages were impressed on the rocks before their regional thermal metamorphism, which has produced a mimetic crystallisation. The general conclusion drawn from this work by Dr. Richey is that folding movements (the Morar Anticline) transformed the rocks into slightly metamorphosed sandstones and slates and that, later, they were completely recrystallised by heat with the aid of the necessary solvents, to form psammitic granulites and mica-schists, but without any marked directed pressure.

An excellent summary article by G. Wilson on " The Relationship of Slaty Cleavage and Kindred Structures to Tectonics " (*Proc. Geol. Assoc.*, LVII, Pt. 4, 1946, 263–302) will be a godsend to students of the tricky subjects of slaty cleavage, rock fracture, fracture cleavage, drag-folding, lineation and schistosity, in which mechanics

makes a close contact with geology. The paper also seeks to expound the uses of the above structures in the solution of structural problems, not only in purely scientific, but also in economic geology. Dr. Wilson's study serves as an introduction to the rather abstruse subject of petrofabrics and structural petrology which is rapidly becoming a powerful instrument in structural investigations.

E. Cloos's paper on " Oolite Deformation in the South Mountain Fold, Maryland " (*Bull. Geol. Soc. Amer.*, **58**, 1947, 843–918) provides a good illustration of the methods mentioned in the previous paragraph. The South Mountain Fold is a large, asymmetrical, overturned anticline in the Cambrian and Ordovician rocks of the southern Appalachians. It is peculiarly suitable for exact measurements, as several oolitic limestones are involved, the regular spherical units of which, such as ooliths, spherulites, mud-pellets, etc. (collectively called " oöids "), registering the deformations very exactly by their distortions. All parts of the fold participate in and reveal an identical plan of deformation ; the fold axes are nearly horizontal, the cleavage dips south-east, and lineation is in the cleavage plane normal to the fold axes also dipping east. From measurements of the distortion of the oöids the fold is interpreted as a " shear fold " as distinct from a flexure, and deformation is thought to be due to laminar flow on sub-parallel planes.

The experimental deformation of a monomineralic aggregate has been studied by E. B. Knopf in a paper entitled " Fabric Changes in Yule Marble after Deformation in Compression, Part I " (*Amer. Journ. Sci.*, **247**, 1949, 433–61 ; 537–69). The Yule calcite-marble which was used has a simple pattern of preferred orientation. It was deformed under confining pressures of about 10,000 atmospheres at 20° C. and 150° C., both in the dry state, and in the presence of carbonated water. The results of the study indicate the operation of intragranular gliding, and suggest intragranular movement on two sets of intersecting glide-planes ; but conclusive proof of this awaits more detailed experimental work and measurements on thinner sections than were used in this study. It has been established, however, that a radical change in preferred orientation, both dimensional and crystallographic, is caused by the deformation, and that this change is controlled by the fabric pattern of the undeformed marble.

At the request of Mrs. E. B. Knopf, F. J. Turner has made a detailed study of the " Preferred Orientation of Calcite in Yule Marble " (*Amer. Journ. Sci.*, **247**, 1949, 593–621) for later comparison with the fabric of the same rock when artificially deformed. He has described the preferred orientation along several crystal

directions, and has discussed the nature and possible origin of space-lattice orientation of the calcite grains. Many lamellæ of the form $\{01\bar{1}2\}$ are probably due to translation rather than to twin gliding. Other lamellæ are believed to have been produced by a mild, relatively late deformation later than that responsible for the observed space-lattice orientation.

In writing on " The Significance of Thermal Structure in the Scottish Highlands," W. Q. Kennedy (*Geol. Mag.*, LXXXV, 1948, 229–34) gives a " thermal map " of the region showing the location of the sillimanite, kyanite, garnet, biotite and chlorite zones. In this map the Highlands north of the Great Glen Fault are shifted 65 miles to the north-east to allow for the lateral displacement which Professor Kennedy has demonstrated along that line. When that is done the metamorphic zones north and south of the Great Glen Fault join up naturally and form a simple anticline of " thermal surfaces " which pitches to the south-west. The high-temperature sillimanite zone thus forms a core which emerges to the north-east from beneath the other zones. This structure is related in a simple way to Vening Meinesz's conception of a tectogen or mountain root. The successive zones of metamorphism upwards and outwards over the site of the tectogen are due to heat generated by the melting of the mountain root and the ascent of re-melted granitic material. To the latter is ascribed the widespread injection and migmatisation of the folded rocks, regional metamorphism at higher levels, and the ultimate emplacement of granitic batholiths.

Professor Kennedy follows the foregoing with a paper on the " Zones of Progressive Regional Metamorphism in the Moine Schists of the Western Highlands of Scotland." (*Geol. Mag.* LXXXVI, 1949, 43–56). His abstract is so concise that the writer makes no apology for transcribing it here : " The Moine Schists of Western Inverness-shire and North-West Argyll show a progressive increase in metamorphism when traced from the outcrop of the Moine Thrust-plane eastwards towards the central area of regional injection and migmatisation. It is possible to distinguish four zones of progressive metamorphism characterised by the development of distinctive mineral assemblages in the very subordinate, but widely distributed and highly distinctive calc-silicate granulites. The easterly increase in grade is attributed to the thermal effect of the great injection complexes, and it is suggested that the Torridonian, the Tarskavaig Moine Schists, and the Moine Schists proper merely represent successive stages in the regional metamorphism of one formation."

In a study of " Earlier Stages in the Metamorphism of Siliceous

Dolomites," C. E. Tilley (*Min. Mag.*, XXVIII, 1948, 272–6) shows that, in the outer aureole of metamorphism of the Cambrian dolomites of Broadford-Kilchrist area of Skye, the first-formed mineral is talc, which appears around the peripheries of chert nodules in the limestone. Farther in towards the granite contact tremolite makes its appearance and talc diminishes and ultimately disappears. Forsterite and diopside are recognised as the products of still higher grades of metamorphism, but their appearance depends on diminution of the vapour pressure of CO_2, perhaps through the activity of circulating solutions. Neither enstatite nor anthophyllite are formed during the metamorphism of these siliceous dolomites, as they appear to be unstable in the presence of calcite. These phases would be expected to appear in more highly magnesian assemblages than the above quartz-dolomite associations.

Taking over earlier work in collaboration with W. Q. Kennedy, C. E. Tilley publishes a preliminary note on " Dolomitic Contact Skarns of the Broadford Area, Skye " (*Geol. Mag.*, LXXXV, 1948, 213–16). These extremely interesting rocks are divisible into two groups : (1) skarns at the immediate contact with the granite, characterised by minerals stable in the presence of free silica— grossular, wollastonite, diopside, hedenbergite and plagioclase. These are derived from the silication of the dolomite. (2) Skarns on the limestone side of the contact zone, especially characterised by magnetite ore with undersilicated minerals—forsterite, monticellite, humite group and cuspidine. Clinopyroxene is often important in this group. This assemblage is associated with a boron—fluorine pneumatolysis.

F. H. Stewart has provided " Chemical Data on a Silica-poor Argillaceous Hornfels and its Constituent Minerals " (*Min. Mag.*, XXVI, 1942, 260–6). The rock is near the margin of the basic intrusion of Belhelvie (Aberdeenshire) and is described as garnet-spinel-cordierite-plagioclase-biotite-hornfels. Mr. Stewart has made analyses of the rock itself and of the constituent garnet, spinel, cordierite and biotite. The cordierite is peculiar in being an optically positive variety.

W. S. MacKenzie describes " Kyanite-gneiss within a Thermal Aureole " (*Geol. Mag.*, LXXXVI, 1949, 251–4). He records the fact that kyanite is much more widespread in the Moine rocks of the Ross of Mull than has hitherto been recognised. Where the kyanite-gneiss enters the aureole of the Ross of Mull Granite large paramorphs of andalusite are formed from the kyanite by thermal metamorphism.

In a paper on " Coronas and Coronites," S. J. Shand (*Bull. Geol.*

Soc. Amer., **56**, 1945, 247–66) summarises the observations and opinions of many authors, and supplies further evidence from analyses of coronites from the Adirondacks and eastern Quebec. Coronas are not products of the magmatic period of crystallisation or they should be much more common than they are ; neither are they deuteric crystallisations from hot aqueous solutions. Dr. Shand favours the view that the chief factor in corona formation may be the instability of olivine under thermal metamorphism. The characteristic minerals of coronas are mostly foreign to eruptive rocks, but all of them are typical products of thermal metamorphism.

An unusual kind of paper is published by W. O. Williamson on " Ceramic Products, their Geological Interest and Analogies " (*Amer. Journ. Sci.*, **247**, 1949, 715–49). It bears mainly on metamorphic processes. The following is the author's abstract : " Some phenomena of the ceramic industries are analogous to processes believed to operate in igneous, metamorphic and sedimentary petrogenesis. The shaping of clays and the deformation of rocks produce comparable petrofabrics. The interaction of igneous and country rock is paralleled by that of silicate-melt and refractory. Fronts and culminations exist in slagged refractories, but there is no evidence that they are produced by solid diffusion. Ceramic phenomena that suggest the operation of solid diffusion are, however, recorded." Thus, recrystallised monomineralic artificial products show analogies to thermally metamorphosed quartzites and marbles. Silica bricks resemble siliceous xenoliths. There are analogies between the action of glasses and slags on refractories and that of igneous masses on country rocks. Skarns and zonary structures are produced at contacts between silicate melts and ceramic materials. Migration of a melt rather than solid diffusion appears to be involved in their production.

Australasian metamorphic rocks have received much attention in recent years. Rather late in the day C. O. Hutton's important memoir on " Metamorphism in the Lake Wakatipu Region, Western Otago, New Zealand " (*N.Z. Dept. Sci. & Indus. Res., Geol. Mem. No. 5*, 1940, 84 pp.) has come to our notice. The rocks involved are a thick series of quartzo-feldspathic sediments interstratified with argillaceous and ferruginous bands, which were subjected in the Palæozoic to regional dynamothermal metamorphism associated with the intrusion of granitic batholiths which are believed to be the source of tourmaline in the schists. The metamorphic types produced are low-grade quartzo-feldspathic schists belonging to the chlorite zone. The latter is divided into four sub-zones based on the degree of reconstitution suffered by rocks of greywacke

composition. The whole series closely resembles that of the southern margin of the Grampian Highlands of Scotland. The memoir is full of valuable detail for the metamorphic petrographer, and is illustrated with good figures of thin sections and new analyses of the metamorphic rocks and minerals.

Dr. Germaine A. Joplin has published a series of papers dealing with " Petrological Studies in the Ordovician of New South Wales " ; " I. The Cooma Complex " (*Proc. Linn. Soc. N.S.W.*, lxvii, Pts. 3–4, 1942, 156–96), " II. The Northern Extension of the Cooma Complex " (*ibid.*, lxviii, Pts. 5–6, 1943, 159–83) ; " III. The Composition and Origin of the Upper Ordovician Graptolite-bearing Slates " (*ibid.*, lxx, Pts. 3–4, 1945, 158–72) ; " IV. The Northern Extension of the North-east Victorian Metamorphic Complex " (*ibid.*, lxxii, Pts. 3–4, 1947, 87–124). She shows that the Cooma Complex consists of two units ; an upper (Coolringdon Beds) consisting of sandstones and siliceous slates, and a lower series (Binjura Beds) which originally consisted of sandstones, aluminous shales, tuffaceous sandstones and small flows of basalt. The Binjura Beds have been invaded by ultrabasic and basic masses, and later by a body of granite-gneiss which is held to be responsible for their partial granitisation. Various zones of metamorphism are traced in the non-granitised rocks, together with two zones of granitisation, an outer zone of permeation and an inner of injection. Chlorite, biotite and andalusite zones are recognised ; and, although all the metamorphism belongs to the same tectonic disturbance, there is evidence that the andalusite zone is a contact metamorphism superposed upon an earlier dynamometamorphic phase. Paper No. II describes a northern extension of metamorphic zones mapped on the western side of the Cooma Complex.

The graptolite-bearing slates are next dealt with (No. III). They are shown to be highly siliceous, and the siliceous composition is probably original. In the course of a valuable discussion of the origin of black shales Dr. Joplin suggests that the slates in question have been formed as the result of large accumulations of fine siliceous volcanic ash which encased and preserved the organic matter which was deposited at the same time.

Paper No. IV deals with another region (Albury) in the great metamorphic complex of north-eastern Victoria and the adjacent parts of New South Wales. It, too, consists largely of Ordovician schists in which chlorite and biotite zones have been recognised, along with a zone of knotted schists and a zone of granitised schists. The metamorphic pattern has been much obscured by the contact effects of later granites.

A. B. Edwards and G. Baker discuss " Contact Phenomena in the Morang Hills, Victoria " (*Proc. Roy. Soc. Vict.*, LVI, Pt. 1 (N.S.), 1944, 19–34). The Morang Hills consist of Silurian mudstones and shales in contact with a mass of Devonian granodiorite. The sediments show progressive metamorphism through spotted muscovite-hornfels and biotite-hornfels to coarse cordierite-biotite-hornfels, as the granite contact is approached. At another place sillimanite-andalusite-hornfels rich in orthoclase has been developed. All these contact metamorphic rocks are obviously rich in potash ; and the granodiorite, otherwise normal, passes into a potash-rich phase with giant crystals of orthoclase at the contact. The authors derive this potash-rich phase from assimilation of the potash-rich contact rocks mentioned above. It is but fair to say that a very different interpretation would be put on these phenomena by the granitisation experts.

Sir Douglas Mawson and E. R. Segnit have described some extraordinary " Barium-rich Aplitic Gneisses of Broken Hill (N.S.W.) " (*Trans. Roy. Soc. S. Austr.*, 70 (2), 1946, 277 93), and E. R. Segnit has further analysed and determined the optical constants of the " Barium felspars from Broken Hill, N.S.W." (*Min. Mag.*, XXVII, 1946, 66–74). The high-barium rocks are pale aplitic gneisses with up to 15 per cent BaO, distributed as lenses and streaks in an acid gneiss which contains only the normal amount of BaO (0·09 per cent.). The minerals determined by Mr. Segnit are celsian, calciocelsian (variety of celsian with about 4 per cent. of CaO), hyalophane and barium plagioclase. The authors consider that the barium-rich aplites occupy minor shear zones, and were probably introduced as late-crystallising fractions of the granodiorite magma of the area. Transitional types between the granodiorites and aplites have been found.

" Regional Metamorphism in the Kenogamisis River Area (Ont.) " has been studied by R. D. MacDonald (*Journ. Geol.*, LII, 1944, 414–23). Pre-Cambrian sediments of slate-greywacke type, and volcanic rocks ranging from acid to basic, have been subjected to a regional metamorphism. The rocks produced are quartz-albite-chlorite-sericite-schists, sometimes with actinolite and epidote, in the chlorite zone ; quartz-oligoclase-biotite-schists, with hornblende in some instances, in the biotite zone ; quartz-oligoclase-biotite-garnet-schists often with staurolite, in the garnet zone. The retention of bedding structures shows that dynamic action could not have been great, and the main metamorphism is ascribed to a granite mass towards which the metamorphic grade increases.

According to R. W. Chapman in a paper with the intriguing

title " Pseudomigmatite in the Piedmont of Maryland " (*Bull. Geol. Soc. Amer.*, **53**, 1942, 1299–1330), the Laurel Gneiss, which " looks like, and which had hitherto been thought to be, a true migmatite due to thorough penetration and assimilation of schists and quartz-ites by granitic magma, is to be regarded as a ' pseudomigmatite.' " That is to say, it is believed to have arisen by the granulation, flowage and recrystallisation of the Wissahickon formation under conditions of stress, high temperature and abundant water, but without the co-operation of granite magma. This view is suggested by the absence of intrusive contacts, the mineralogy and chemistry of the rocks, similarity of the two bodies of rock, the abundance of relatively uncrushed remnants in the midst of granulated and recrystallised gneiss, and the completely gradual transition from the Laurel Gneiss into the Wissahickon Schists. This is clearly another case of an " igneous-looking " rock which has not been formed by magmatic processes.

Describing the " Petrography, Structures, and Petrofabrics of the Pinckneyville Quartz-diorite, Alabama," H. R. Gault (*Bull. Geol. Soc. Amer.*, **56**, 1945, 181–246) shows that coarse quartz-diorite-gneiss constitutes the major part of the complex, with smaller amounts of granodiorite- and granite-gneiss. Some hornblende-biotite-gneisses probably represent earlier basic sills and dykes. The complex includes septa of schist parallel to the regional strike. The sequence of intrusion is quartz-diorite, granodiorite, granite. All the rocks contain small but persistent amounts of allanite and epidote. The dominating trend of inclusions, foliation, lineation and contacts, is north-east to south-west, and the petrofabric analysis confirms this and other structural indications. It is concluded that the igneous mass was syntectonic, and that intrusion took place under conditions of regional metamorphism.

C. H. Johnson has described " Igneous Metamorphism in the Orofino Region, Idaho " (*Journ. Geol.*, LV, 1947, 490–507). A complex series of metamorphic rocks lies west of the great Idaho Batholith of quartz-diorite. Petrographically many of them resemble types of quartz-diorite and granodiorite, but they occur in parallel layers which suggest bedding, and grade into pure quartz-ites on the one hand, and into true igneous rocks on the other. On the whole their structures are gneissic, but there are minor massive and schistose facies. These rocks are considered to have been " granitised " ; they were originally siliceous sediments and have been changed by hydrothermal solutions soaking in from the adjacent batholith.

In a paper " On Amphibolitic and related Rocks from Western

Celebes and the southern Sierra Nevada, California," C. G. Egeler (*Proc. Kon. Nederland. Akad. v. Wetensch.*, *Amsterdam*, Ll, 1948, 100–5) discusses the superposition of two different types of amphibolitic metamorphism, a common feature in western Celebes, in relation to a somewhat similar occurrence in the Sierra Nevada (Cal.) which has been described in an important paper by C. Durrell (" Metamorphism in the Southern Sierra Nevada, North-east of Vesalia, Cal." *Univ. Cal. Publ. Bull. Dept. Geol.*, **25**, 1940, 1–118), which the writer unfortunately has not seen. Apparently, in both regions, there has been an older regional metamorphism of dynamothermal type producing rocks of the epidote-amphibolite or epidiorite facies including the type named, as well as amphibolites and hornblende-schists of somewhat higher grade. A later intensive plutonic metamorphism arising from the intrusion of great masses of granodiorite has been superposed on the earlier type, leading to the imposition of a higher amphibolitic facies in Celebes and a pyroxene-hornfels facies in California.

C. G. Egeler's memoir " Contribution to the Petrology of the Metamorphic Rocks of Western Celebes," *Geol. Explorations in the Island of Celebes* (*H. A. Brouwer*), 1947, 175–346) consists largely of the routine description of rocks ranging over practically the whole gamut of metamorphic types. There are some remarks of a more general character at the end. Apparently most of the rocks belong to the greenschist, epidote-amphibolite, amphibolite and granulite facies. The amphibolite facies dominates the region. It is divided into the staurolite-amphibolite sub-facies, and two other sub-facies for which the names andalusite-amphibolite and sillimanite-cordierite-amphibolite are proposed.

ZOOLOGY. By H. G. Vevers, M.B.E., M.A., D.Phil , Marine Biological Laboratory, Plymouth.

Colours and Patterns in Feathers.—Any work on the morphogenesis of feather patterns should be based on a clear understanding of the sequence of events in feather development. The earlier works on this subject were the result of painstaking morphological observations and were, in the main, quite correct. Unfortunately, however, a new theory of feather development was put forward by Lillie and Juhn (*Physiol. Zool.*, 1932, **5**, 124), which was apparently linked with the authors' interpretation of the origin of certain feather patterns. This theory was severely, but justifiably, criticised by Hosker (*Phil. Trans. Roy. Soc.*, B, 1936, **226**, 143) and by 'Espinasse (*Proc. Zool. Soc. Lond.*, A., 1939, **109**, 247), who showed that the classical account was essentially correct. The main point at issue

is the interpretation of the process of shaft formation in the developing feather. According to the classical accounts, the feather shaft develops from a ridge of strictly shaft-forming cells to which the barbs become attached at their proximal ends. Lillie and Juhn (*loc. cit.*) introduced the term " collar " to denote the ring of *stratum Malpighi* cells proximal in the feather germ to the barb ridges. They considered that the collar grew distalwards at the dorsal point of the feather germ and that the shaft was formed by the concrescence of these two collar halves. In addition they stated that, as the collar tissues of the two sides grew together, the primary barb ridges were carried dorsally and distally by what they termed " tangential movement ".

In his criticism of this theory 'Espinasse (*loc. cit.*) has emphasised that the formation of the ridges, as forerunners of the barbs, is a relatively passive process, and that there is no evidence for a movement of cells, such as might occur if the two collar halves were to fuse in the mid-dorsal line. More recently Lillie and Juhn (*Physiol, Zool.*, 1938, **11**, 434) and Lillie (*Biol. Rev.*, 1942, **17**, 247) have modified their views on the origin of the shaft, and it appears that they now admit that the central part of the shaft is formed in accordance with the classical theory, but they still consider that concrescence plays a part in the formation of the lateral surfaces of the shaft. In spite, however, of this controversy, much valuable work on feather pattern has been done in recent years.

Melanin pigments in Feathers.—Most feathers owe their colours to the presence of a melanin pigment, which may range in colour from yellow-buff through red-brown to black. There are also some yellow or red feathers which are pigmented by carotenoids. Earlier workers classified the melanins into a phæomelanin group, occurring as yellowish to dark red-brown granules which could be dissolved in 2 per cent. alkali, and a eumelanin group, occurring as dark-brown or black granules which were only soluble in 35 per cent. alkali. The eumelanins were supposed to occur as rod-shaped granules, and the phæomelanins as roughly spherical granules. F. Frank (*J. Ornith.*, 1939, **87**, 426) has, however, pointed out that the shape of the pigment granule is determined by the form of the colourless pigment core round which the melanin is deposited. He found that blackish melanin could exist in the form of spherical or rod-shaped granules. The earlier solubility investigations on melanins, in which the feathers were merely treated with different concentrations of alkali, took no account of the inaccessibility of the melanin embedded in the keratin, nor of the partial solution of the keratin itself. From his own work Frank concluded that the

different melanin types occurring in feathers should be described on the basis of the length of time it takes to obtain almost complete solution in a given volume of alkali.

Frank (*loc. cit.*) has also been able to add to our knowledge of blue colours. It has long been known that blueness in feathers is due, not to a blue pigment, but to the presence in the feather barbs of a turbid porous layer overlying a more ventral deposition of melanin. The exact form of the turbid layer has, however, never been settled, for the small size of the blue-producing elements has necessarily made it impossible to investigate them by ordinary microscopical technique. It was generally considered that the turbid layer consisted of keratin containing ultramicroscopic tubular air-filled spaces. Much of the evidence suggesting this interpretation has been obtained by observations on the penetration of the turbid layer by impregnating fluids. Frank also employed this method and concluded that the blue-producing cells do not have a complicated tubule structure, but rather a relatively simple, porous, spongy system of air-filled microvacuoles. In confirmation of this he published electron micrographs of barb sections which show that the walls of the turbid layer cells do contain a fine structure of roundish spaces. Feathers showing this type of blue structure are common among the pigeons, macaws and many other birds. Melanin occurs in both barbs and barbules, but, except in blue feathers, it is mainly in the barbules that it plays its part in colouring feathers.

In ordinary dull-surfaced feathers it is only the edge of each pigmented barbule which is presented to the observer, and the combined effect of many thousand such barbule edges is to give a matt appearance to the whole. However, in many birds the visible surface of the feathers is iridescent, and in such cases the hooked barbules are twisted proximally so that they present a broad side to the observer. It is the roof-like pattern of these flat barbule surfaces, each with its associated thin film structure overlying a layer of melanin granules, which provides the basis for iridescent or subjective structural colours.

Pigment Deposition.—The actual work of pigment deposition in feathers is carried out by chromatophores, easily seen in transverse sections of developing feather germs. H. L. Eastlick (*J. Exp. Zool.*, 1939, **82**, 131) has shown that cells which lie close to the neural tube in the 24 to 32 somite stages (neural crest cells) are responsible for pigment production. By transplanting small pieces of embryo skin from robins to the developing wing bud of White Leghorn host embryos, Mary E. Rawles (*J. Genet.*, 1939, **38**, 517) was able to show that in this combination the pigment was produced by the donor

(robin) melanophores, which migrated from the grafted tissue into the epidermal tissue of the developing host (White Leghorn) feather germs. The structure of the barbules of the resulting robin-coloured feathers was, however, the same as that of the Leghorn host and quite unlike that of the donor robin. Furthermore, although the shape, size and colour of the pigment granules in the graft area were the same as those of a normal robin, the granules were evenly scattered throughout the cells, as in coloured fowl races, instead of being massed at the barbule nodes as in the robin.

Sexual Dimorphic Plumage.—In many birds, *e.g.* the crows, the sexes are similarly feathered and both may show iridescence, but where there is sexual dimorphism, as in Gallinaceous birds, the male bird is usually brightly pigmented, and it also shows iridescent structural coloration. In the common fowl, for instance, it is well known that plumage type and coloration are both controlled by the sex hormone environment. In Brown Leghorns the salmon-pink of a male soma feather is replaced by dark-brown in the presence of ovarian secretions or œstrogenic compounds, and in a barred race of fowls C. W. Emmens and A. S. Parkes (*J. Genet.*, 1940, **39,** 503) have found that œstrogen injections into capons induce the female type of barring. This apparent equipotentiality of the sexes as regards plumage may therefore hold good for the feathers of some races of the common fowl, but there are numerous birds, *e.g.* certain passerines, where sexual dimorphic plumage characters appear to be under genetic control. F. A. E. Crew and S. S. Munro (*Proc. Roy. Soc. Edin.*, 1938, **58,** 114) have described a gynandromorphic Gouldian finch. This bird was a genetic female with male coloration on the slightly larger right side and female on the smaller left side, and with an ovary on the left and no trace of testicular tissue. They showed that in this species male and female feather colours are purely genetic characters, and they use the term " sparrow-type " to describe this method of plumage control, as distinct from the " fowl-type " in which the plumage characters are apparently all subject to the hormonal environment, so that bilaterality of plumage in fowls is virtually impossible. To describe a third group of gynandromorphic birds Crew and Munro used the term " pheasant-type " : in these birds a nearly normal sex type of plumage occurs on one side and an intersexual type on the other.

This pheasant-type is perhaps the most interesting type of plumage control which has come to light in recent years. The brilliant plumage of cock pheasants does not develop in the capon treated with œstrogens. Instead, the new feathers are light and

dark-brown in colour as in the female, but the pattern is not the same. C. H. Danforth (*J. Exp. Zool.*, 1937, **77**, 1, and *J. Genet.*, 1937, **34**, 497) analysed the plumage of certain pheasants by means of skin transplantation and found that male skin grafted on to a female produced brown feathers quite distinct in pattern from the surrounding true female feathers of the host. In these cases, therefore, while the pigment types (perhaps in the pheasant they are different stages of oxidation of melanin compounds) are under hormonal control, the configuration of the pattern on the feather vane is probably under genetic control. Exactly opposite to this conclusion is the observation of Stella (*Arch. Zool. Torino*, 1934, **20**, 237) that, in Goldenlaced Wyandottes, males treated with an œstrogen produced feathers which were female in shape, structure and pattern, but which retained the dark shade of yellow characteristic of the male. There are, therefore, considerable differences in the extent to which each feather character may be influenced by external factors.

From the endocrinological viewpoint A. S. Parkes and C. W. Emmens (*Vitamins and Hormones*, Vol. II, New York, 1944, pp. 361 -408) have summarised work on the effect of androgens and œstrogens on birds. Besides giving the chemical composition of these substances, they also deal in some detail with the method of prolonging the effect of certain of them by using esters in place of free hormones. In *Biological Action of Sex Hormones* (2nd edition, Cambridge, 1949) H. Burrows has produced a monograph which brings together all the available information on the action of sex hormones on various organs in mammals. This book should be of great value to all who are working on the effects on animals of natural and synthetic hormone preparations.

NOTES

Swimming of Dolphins (G. A. Steven.)

In view of the present interest in the swimming powers of dolphins and similar animals,[*] the following observations made some years ago may be of value. Unfortunately one page of the original notes has been lost and with it the actual date of the observations and some other relevant information. The observations were made when the writer was serving in a vessel on passage with another vessel in tow. The proper towrope had twice parted and the one in use at the time was made up from several lighter wires lashed together at intervals. One of the lashings had a loose end that hung down and frequently touched the water astern of the towing ship from which the observations were made : its distance off was later accurately ascertained when the towrope was hove in.

At one period dolphins were present around both ships and were frequently observed coming up from astern and overtaking the towing ship. It was possible, therefore, accurately to note the instant when a dolphin passed the hanging end of the loose lashing on the towrope and also when it had reached a position directly opposite a certain point on the ship. The distance between the lashing and this point proved to be 208 ft. Seven readings of the time taken by a dolphin to pass between them were obtained, the speed at the time being 6¼ knots.

Animal No.	1	2	3		
Time (in seconds)	9	10	9½	9¼	10½

This, in animals 1 and 6, represents a distance of 208 ft. + 94 ft. (due to speed of ship) covered in 9 seconds, which gives a speed of 33·5 ft. per second—i.e. 20 knots almost exactly.

The dolphins observed were all approximately of the same' length, which I judged to be 7 ft. or just under. Moreover, what appeared to be the same dolphin was observed on two occasions approaching from astern. It thus appears that the " school " was playing backwards and forwards from ship to ship although no

* A. V. Hill, " The Dimensions of Animals and their Muscular Dynamics," SCIENCE PROGRESS, 1950, **38**, 209.

animals were seen making the reverse journey. This was probably done some distance off.

It is not improbable that the speed of 20 knots exhibited by animals 1 and 6 represents fairly accurately the maximum speed of which dolphins about 7 ft. in length are capable, even in short bursts ; for in overtaking from astern it seems quite likely that the animals might have been going " all out " to catch up.

For a short period during which she was parted from her " tow " the towing ship was doing 9 knots. Dolphins were again present at this time and several counts were obtained of the tail beats of a single animal that stayed for a considerable period close in front of the forefoot and was therefore doing 9 knots too. It did not appear to be falling continuously down the bow wave. The counts were made over 10-second periods.

Observation No.	1	2	3	4	5	6	7	8	9
Tail beats/10 secs.	27	25	26	26	26	23	24	26	27

What the beats were when the animal accelerated and disappeared ahead of the ship could not be determined. Nor could I get any good idea of the amplitudes, but they appeared to be small.

In his lecture (*loc. cit.*) Professor Hill quotes me as having informed him orally that a dolphin swimming in phosphorescent sea produces as a wake a clean line of phosphorescent light. Unfortunately this is not strictly correct. Dolphins in such circumstances usually produce a pronounced double wake consisting of *two* clean diverging lines of luminescence stretching behind them, with very little luminescence (turbulence) in between.

Fig. 1.—Diagram of pattern formed by the double wakes of two dolphins whose paths have crossed. The arrows indicate the direction in which the animals were moving.

If two dolphins cross each other's paths at close range, a definite pattern can sometimes be observed (Fig. 1). These clean dolphin wakes are very different from the boiling mass of turbulence produced by a seal swimming at speed.

All animals on which the observations were made appeared to be common dolphins, *Delphinus delphis.*

The Wood Anatomy of the Proteaceae [*] (F. W. J.)

The Proteaceae forms a large family of some 54 genera and over 1000 species which are almost exclusively trees or shrubs. Over half the species are Australian and many are endemic to that continent : South Africa claims about 300 species, while others occur in Eastern Asia and the Pacific and in South America.

Economically, few of the Proteaceae are of much value, although several are large trees which yield commercial timber. Such are the silky oaks (*Cardwellia sublimis, Orites excelsa* and *Grevillea robusta*) of Australia, the rewarewa of New Zealand (*Knightia excelsa*) and the South African terblanz (*Faurea Macnaughtoni*). Most species produce handsome flowers which, with their copious nectar, are valuable as a source of honey.

One of the most characteristic features of proteaceous wood is the large rays which, in *Xylomelum*, may form as much as 50 per cent. of the wood. Certain species of *Persoonia* are exceptional in possessing small rays only. In *Banksia* and *Dryandra* the rays possess vascular tissue, and in tangential sections such rays have the appearance of small stems viewed in cross-section. Stone cells are found in the rays of some genera. The vessels tend to be arranged tangentially and are often associated with parenchyma, so that in transverse section vessels and parenchyma appear as festoons between the large rays. This arrangement, however, is not always seen ; in *Cardwellia*, for example, the vessels are more or less irregularly distributed. While the vessels have predominantly simple perforations, reticulate and foraminate plates are not uncommon in *Lomatia* and *Telopea*. The vessels appear to be free from tyloses. The parenchyma is variable, but in general tends to form tangential bands between the rays.

The large rays and, in transverse section, the tangential arrangement of the parenchyma and vessels are sufficient to distinguish woods of this family from any other woods with large rays. Where the " festoons " of vessels and parenchyma are less distinct there is possibility of confusion, but the resemblances to woods of certain other families are, even so, more apparent than real. It is only in proteaceous woods without large rays that difficulty arises in distinguishing the timber.

Dr. Chattaway describes the anatomy of 26 genera of the family. She finds that species of these genera are generally not distinct enough to be separated with certainty.

There does not appear to be any very close relation between

[*] By M. Margaret Chattaway, *Austr. J. Sci. Res.*, *Ser. B.*, **1**, 279–302, 1948.

the botanical classification proposed for the family by Engler and Prantl (1889) and the wood structure, and it would appear that at present the structure of the xylem is of little help for taxonomic purposes in this family.

" Journal of the Science of Food and Agriculture " (N. M. C.)

It is very significant that the Society of Chemical Industry is producing this new journal. The chemistry of agriculture has never had the place in the sphere of chemical industry that agricultural chemists would deem to be its right. One main reason is the fact that the chemistry of agriculture, that is the chemistry of primary production, is divorced (rightly so for many reasons) from the chemistry of processing the products for human use, and its interest (although not its importance) is therefore in a restricted field.

This journal, dealing with agriculture and with food— the chief, but not the only, product of agriculture—should therefore be very welcome, and its issue marks the development of an interest in the work by the Society of Chemical Industry that has been growing for some years.

This first number (January 1950) has some words of welcome from the Ministers of Agriculture and of Food and also from the President of the Society, and there is a valuable article by Viscount Bruce on the work of F.A.O. All this is specific to the first issue. The papers that forecast the intended character of the journal deal with the ascorbic acid in black currants, the analytical data of fruit juices, vitamin content of certain vegetables, the quality of bread, the composition of seal oil, the fat of dehydrated herrings, and the effects of sulphur dioxide on orange juice.

It should be a very acceptable journal. The annual subscription is 30s., post free ; single copies 3s., post free.

Miscellanea

The following were elected to be Fellows of the Royal Society at the meeting held on March 16 : Dr. B. P. Babkin, physiologist, McGill University, Montreal ; Prof. L. F. Bates, professor of physics, University of Nottingham ; Prof. T. A. Bennet-Clark, professor of botany, King's College, London ; Dr. B. Bleaney, demonstrator and lecturer in physics, University of Oxford ; Dr. L. J. Comrie, director of the Scientific Computing Service, Ltd., London ; Prof. C. A. Coulson, professor of theoretical physics, King's College, London ; Dr. L. R. Cox, assistant keeper, Department of Geology, British Museum (Natural History) ; Prof. H. S. M. Coxeter, professor of mathematics, University of Toronto ; G. H. Cunningham,

director of the Plant Diseases Division, Department of Scientific and Industrial Research, Auckland, New Zealand ; Dr. W. J. Elford, biophysicist, National Institute for Medical Research, London ; S. B. Gates, a senior principal scientific officer, Ministry of Supply (Air) ; Dr. C. A. Hoare, protozoologist to the Wellcome Laboratories of Tropical Medicine, London ; Prof. L. Howarth, professor of applied mathematics, University of Bristol ; Prof. E. R. H. Jones, professor of organic chemistry, University of Manchester ; Dr. A. J. P. Martin, biochemist, National Institute for Medical Research, London ; Dr. D. F. Martyn, principal scientific officer, Commonwealth Scientific and Industrial Research Organisation, Solar Observatory, Canberra ; Prof. R. A. Morton, professor of biochemistry, University of Liverpool ; Prof. R. J. Pumphrey, professor of zoology, University of Liverpool ; Prof. A. G. Shenstone, professor of physics, University of Princeton, formerly scientific liaison officer in London of the Canadian National Research Council ; Prof. H. E. Shortt, head of the Department of Parasitology, London School of Hygiene and Tropical Medicine ; Prof. M. Stacey, professor of chemistry, University of Birmingham ; Dr. L. E. Sutton, demonstrator and lecturer in physical chemistry, University of Oxford ; R. L. M. Synge, biochemist, Rowett Research Institute, Aberdeenshire ; Dr. B. P. Uvarov, director of the Anti-Locust Research Centre, British Museum (Natural History) ; Prof. F. C. Williams, professor of electro-technics, University of Manchester.

H.M. the King has approved the award of the Royal Medals of the Royal Geographical Society as follows : Founder's Medal to Mr. George F. Walpole, director, Department of Lands and Survey, Kingdom of the Jordan, for his contributions to the mapping of the Western Desert of Egypt ; Patron's Medal to Prof. Harald Sverdrup, director of the Norwegian Polar Institute, for his contributions to polar exploration, and for his oceanographical investigations. The Council of the Society has awarded the Victoria Medal to Prof. Emmanuel de Martonne, honorary director of the Geographical Institute, University of Paris, and honorary president of the International Geographical Union, for his studies in physical and regional geography.

Other medals awarded during the quarter include the Linnean Medal of the Linnean Society of London to Mr. H. N. Ridley ; Platinum Medal of the Institute of Metals to Prof. Albert Portevin ; Bessemer Medal of the Iron and Steel Institute to Mr. James Mitchell, hon. treasurer, Stewarts & Lloyds, Ltd., and Sir Robert Hadfield Medal of the Iron and Steel Institute to Mr. G. D. Elliot, Appleby-

Frodingham Steel Co., Scunthorpe; the thirty-eighth Progress Medal of the Royal Photographic Society to Prof. John Eggert, of the Swiss Federal Institute of Technology, Zürich. The Meldola Medal of the Society of Maccabæans for 1949 has been awarded, on the recommendation of the Council of the Royal Institute of Chemistry, to Dr. A. J. B. Robertson.

Prof. G. R. de Beer, professor of embryology at University College, London, has become director of the British Museum (Natural History) in succession to Mr. N. B. Kinnear.

Sir Ian Heilbron, director of research of the Brewing Industry Research Foundation, Nutfield, and emeritus professor of organic chemistry in the University of London, has been appointed chairman of the Advisory Council for Scientific and Industrial Research in the place of Sir Geoffrey Heyworth, who resigned owing to pressure of other public duties.

Mr. J. S. Colman, senior lecturer in zoology in the University of Sheffield, has been appointed director of the Marine Biology Station at Port Erin, Isle of Man.

The B.B.C. announces that this year's Reith Lectures will be given by Prof. J. Z. Young, F.R.S., professor of anatomy at University College, London, on the subject of *Doubt and Certainty in Science*. The lectures will be broadcast in the autumn.

We have noted with great regret the announcements of the death of the following scientific workers during the quarter : Prof. J. A. Crowther, emeritus professor of physics in the University of Reading ; Prof. Richard Fosse, formerly professor of chemistry applied to organisms in the Natural History Museum, Paris ; Prof. C. S. Gibson, O.B.E., F.R.S., emeritus professor of chemistry in the University of London at Guy's Hospital Medical School ; Dr. A. E. M. G. Gillam, lecturer in chemistry in the University of Manchester ; Dr. Robert Gurney, zoologist ; Sir Norman Haworth, F.R.S., emeritus professor of chemistry in the University of Birmingham ; Sir James Henderson, formerly professor of applied mechanics, Royal Naval College, Greenwich ; Prof. Alexander Klemin, Guggenheim research professor of aeronautical engineering, New York University ; Dr. H. R. Mill, geographer and meteorologist ; Prof. T. H. Milroy, emeritus professor of physiology, Queen's University, Belfast ; Prof. G. R. Minot, emeritus professor of medicine, Harvard University ; Prof. A. M. Mosharrafa Pasha, professor of applied mathematics and dean of the faculty of science in the Fouad I University, Cairo ; Dr. R. H. Rastall, geologist ;

Prof. J. A. Ryle, professor of Social Medicine in the University of Oxford; Prof. F. W. Twort, F.R.S., lately superintendent of the Brown Institution and professor of bacteriology in the University of London; Prof. S. E. Whitnall, formerly Robert Reford professor of anatomy in McGill University and later professor of anatomy in the University of Bristol; Mr. A. J. Wilmott, deputy keeper in the Department of Botany, British Museum (Natural History); Prof. W. P. Wynne, F.R.S., emeritus professor of chemistry in the University of Sheffield.

We have received a copy of the forty-second Annual Report of the Governing Body of the Imperial College of Science and Technology of London University for the year ending July 31, 1949. The report covers staff changes, an extensive list of publications by members of the College, statements of accounts, and notes on recent developments of College activities. One of these refers to a subject which appears to be new in the Universities of Great Britain, namely Public Health Engineering. The Trustees of the Rockefeller Foundation have offered $27,200 to further the subject during 1949–52, and these funds will be used partly to cover the cost of a Research Fellow at Imperial College and a Tutor at the London School of Hygiene and Tropical Medicine. This venture should help to strengthen the links already existing between the College and Institutions in U.S.A., and further developments will be awaited with interest. Additional evidence of the friendly relations between the College and Industry is afforded by the announcement of the establishment of the Henry Mark Pease Readership in Telecommunications, financed by Standard Telephones & Cables, Ltd., and a lectureship in Concrete Technology, added to the existing Chair in the subject, both financed by the Cement Makers' Federation. The Report includes statements on building plans, with particular reference to the site immediately north of Imperial Institute Road. The departure of the Royal School of Needlework at Christmas 1948 has already allowed much needed expansion of some Departments of the College. In view of recent discussions on the education of technologists, it is interesting to read that a Committee has been appointed to examine the problem of cultural studies in a College primarily devoted to Science and Technology (though it is recognised that there are cultural aspects of these fields of study). The number of full-time students in 1948–49 was 1428 compared with 1510 in the previous session.

The *Journal of Research* of the National Bureau of Standards for January 1950 contains an account by D. B. Judd of the modi-

fication of the colour temperature scale made necessary by the revision of the International Temperature Scale in 1948. The changes arise from the substitution of the Planck radiation formula for the approximate Wien formula and the change of the Wien constant C_2 from the value 1·4320 to 1·4380 cm. deg. C. The colour temperature in question is the temperature at which a black body emits light of the same colour as that emitted by the body whose temperature is required. It has been shown that for tungsten filaments changes in this colour temperature are approximately equal to changes in temperature as indicated by an optical pyrometer using light of wavelength 6500 A. For industrial use the Bureau has issued secondary tungsten lamp standards with certificates stating the voltage required for any specified colour temperature on a scale established in 1934 and based on the original International Scale. Temperatures above those which can be obtained by passing a current through a tungsten filament are determined by passing the light from the glowing filament through colour filters (e.g. of blue glass) which produce colour effects characteristic of temperatures above those of the filament. By the use of lamp-filter combinations, standards of colour temperature are available over the range 1800° to 25,000° K. on the 1934 scale. The present paper gives the corrections which must be applied to values on the 1934 scale to reduce them to the revised (1949) scale. The following list gives some of these corrections, the 1949 values being given between brackets : 1800° K. (1797), 2000 (1996), 2500 (2491), 3000 (2985), 5000 (4940), 10,000 (9680), 25,000 (22,800). It may be mentioned that the freezing-point of platinum on the 1948 international scale is 2042° K. ; the old value (1927 scale) was 2046° K.

A paper by Dahl and Cleaves in the *Journal of Research* for December 1949 describes a new determination of the freezing-point of uranium, using the technique developed at the Bureau for the determination of the freezing-point of platinum. Earlier determinations of the uranium point gave values from 1075° C. to 1800° C., a surprising variation, possibly explained by the fact that, in the presence of certain gases, a casing of crust forms on the surface of the metal when it is heated, causing it to present an appearance of solidity until, at temperatures far above the melting-point, the molten metal succeeds in breaking through the crust. Melting *in vacuo* is indicated, but when that is done there is an evolution of volatile material which deposits on the window above the crucible and interferes with the pyrometer observations. In the experiments now described the metal was heated in an atmosphere of helium to

a temperature about 50 deg. C. above the freezing-point, which was then determined by the cooling curve method. Repetitions of the experiment with the same sample of metal gave values which rose to an upper limit after the material had been maintained in the molten state for some 15 hours, during which time its purity increased to about 99·99 per cent. The value finally adopted for the freezing-point of uranium of this purity was 1133 ± 2° C.

The British Scientific Instrument Research Association has issued a most attractive booklet describing the facilities offer by the Association and illustrated by photographs of the varic laboratories housed in Sira, the country mansion at Elmstead Woo, Chislehurst, which the Association has converted and equipped a cost of £50,000. The work is divided between six departments, electrical, electronic and optical instruments, mechanics, physics and chemistry, with a common workshop and drawing office Membership of the Association is restricted to British firms actually engaged in the manufacture of scientific instruments, but, since 1948, other concerns, in particular large users of instruments, may join as Associate Members having the right to the full services of the Information Department and Library (at 17 Princes Gate, London, S.W.7) and through the Director of Research (A. J. Philpot, C.B E.) or the Information Officer (C. W. Hanson, B.Sc.) to the advice of the research staff on particular problems. The subscription for the class of membership is from £10 to £25 per annum.

The Tin Research Institute has published a booklet containin graphs showing existing data on the thermal equilibria of 35 tir containing binary metallic systems. References are given to the papers containing the data on which the diagrams are based and there is, in addition, a five-page bibliography of publications on all the ternary tin alloy systems which have so far been partly or fully investigated. The booklet can be obtained from the Institute at Fraser Road, Greenford, Middx., price 2s. 6d. post free.

The Institute has pointed out that our supposition on p. 348 of our last issue regarding their journal *Tin and its Uses* is incorrect. The journal is not intended to be a monthly publication, but is published only twice yearly.

The Public Relations Branch of the Office of the High Commissioner for New Zealand, London, issues every fortnight a stencilled *News Bulletin*, containing two or three articles descriptive of conditions in that country. Matters dealt with in recent issues are :

(*a*) A survey of the Labour Force, showing incidentally that the Maori population is now increasing at the rate of 3500 per annum and that the Maoris are choosing to work on secondary industries rather than in farming. (*b*) An account of the work of the Cawthron Institute for Agricultural Research, including the very important soil surveys, the introduction of a parasite which destroys woolly aphis and the discovery that " bush-sickness " in livestock is due to cobalt deficiency. (*c*) Details of the remarkable rural weather forecasting service. By sending a telegram to the Central Office at Wellington a farmer can obtain a local forecast to guide him in planning his operations, or arrange for information to be sent to him when periods of fine or cold weather are likely in his district. The service is widely used by farmers, fishermen, the Forest Service, manufacturers to whom immediate weather conditions or general climatic conditions are of importance, and even by members of the public anxious to choose a fine day for the weekly wash !

The Historical Association (21, Bedford Square, London, W.C.1) has published a pamphlet (G.15, price 1*s.* 7*d.* post free) by Dr. A. Armitage which, under the title *Copernicus and the Reformation of Astronomy*, contains a concise, reasoned and entirely admirable account of the history of ideas concerning the nature of the universe from classical times to the twentieth century. While, as the title suggests, the central theme of the essay is the heliocentric hypothesis proposed by Copernicus in his *De Revolutionibus Orbium Cælestium Libri VI* in 1543, it includes a succinct account of classical and mediæval astronomy, exhibits clearly the parts played by Kepler, Galileo and Newton in the development of the hypothesis, and shows why, seventy-three years after its publication, the book was placed on " the Index of Prohibited Books " and the theory declared " to be unphilosophical if not heretical." There is also some account of Copernicus himself. He became acquainted with the procedure for making astronomical observations as a student at the Polish University of Cracow, studied canon law at Bologna and Padua, took his doctorate at Ferrara, taught for a year at Rome, returned to Padua to study medicine, and, finally, after ten years in Italy, returned " home " to Frauenburg in Ermland, where his uncle, Lucas Waczenrode, as Bishop, was both " spiritual and temporal ruler." Here he was appointed Canon, acted as physician and assistant to his uncle, and later took an increasing share in the government of the Cathedral and the State. He had an apoplectic fit towards the end of 1542 and died in May 1543, having " just received his first copy of his newly printed book."

REVIEWS

Divergent Series. By G. H. HARDY. [Pp. xvi + 396.] (Oxford: at the Clarendon Press, 1949. 30*s.* net.)

THIS book is the last which Prof. Hardy wrote. It is on a subject on which he frequently lectured in Cambridge, and many of us who attended those lectures look back on them as some of the finest he gave. They have now been preserved in a form in which they retain all their freshness, and can be appreciated by a much wider audience.

The book deals with the theory of divergent series in the form which has now become classical. The first two chapters contain many historical references which everyone will find of great interest. Chap. III deals with the general theory of linear transformations by Toeplitz matrices. The results of this chapter are applied in the following chapters, where special methods of summation are considered.

Chaps. V and VI are on Arithmetic Means, and the first of these gives what is probably the most complete account in the literature of the Cesàro, Hölder and Riesz means.

Tauberian theorems for Arithmetic means and for Power series are considered in Chaps. VI and VII respectively. Here Hardy is writing of work to which he, together with Littlewood, made very great contributions. Indeed one cannot help recalling a remark of Wiener's that, had not usage established otherwise, Tauberian theorems might have been more appropriately named Hardy-Littlewood theorems. The chapters on Tauberian theorems are probably the finest in the book. The closely related work of Fuchs and Rogosinski on inclusion theorems for Hausdorff means is given in Chap. XI, and Chap. XII contains a remarkably lucid account of Wiener's Tauberian theorems.

Mathematical literature has been greatly enriched by this work. We are also very much indebted to Dr. L. S. Bosanquet, who assisted Hardy throughout, and saw the remaining proofs through the press, when Hardy was unable to continue working.

A. C. O.

Introduction to Topology. By SOLOMON LEFSCHETZ. Princeton Mathematical Series, No. 11. [Pp. viii + 220, with 74 figures.] (Princeton, N.J.: Princeton University Press; London: Oxford University Press, 1949. 32*s.* net.)

THE student of mathematics who has just graduated and wishes to research in topology is faced immediately by the difficulty of knowing what to read. The best advice in the past has been to gain a sufficient grasp of the German

languago in order to study Seifert and Threlfall's *Lehrbuch der Topologie*, if, by chance, a copy should be available.

Now Prof. Lefschetz has written a textbook whose avowed object is to satisfy the need of the newly-graduated, and he has succeeded, within the compass of some 200 pages, in introducing all the main ideas and theorems required by the beginner. By keeping strictly to polyhedra (*i.e.* rectilinear figures embedded in Euclidean space of sufficiently high dimension), he has facilitated intuitive aids to understanding of the text and avoided the necessity of introducing the more advanced ideas (*e.g.* singular, Čech homology theory), which are encountered later.

The book opens with the foundations of " point-set " topology and proceeds through two-dimensional complexes to the consideration of polyhedral complexes of higher dimensions and, in particular, of manifolds and the various duality theorems appropriate to them. Not only is the classical homology theory given a thorough treatment, but also—and particularly welcome—the more recent Hurewicz homotopy groups (generalisations of the fundamental group) are defined and treated, and theorems relating the homotopy groups to the homology groups are given. So far as the reviewer knows, this is the first textbook dealing with this powerful tool of modern topology. It is, however, a pity that the definition of the homotopy groups in terms of mappings of n-cubes is not also given, for, though the commutativity of the groups is not so obvious, the group operation is very simply formulated.

An excellent feature of the book is the provision of exercises at the end of each chapter which will test the reader's grasp of its contents and develop his ability to use topological arguments. At the end of the book is a bibliography of books and papers on topics treated in the text, the omission from which of M. H. A. Newman's *Topology of Plane Sets* seems unfortunate.

P. J. Hilton.

The Variational Principles of Mechanics. By Cornelius Lanczos. Mathematical Expositions, No. 4. [Pp. xxvi + 307, with 22 figures.] (Toronto : University of Toronto Press ; London : Oxford University Press, 1949. 42s. net.)

It is one of the chief objectives of true mathematicians to seek out the essence of their subject and, as it were, to distil it into its purest and most essential form. Nowhere is this more clearly revealed than in mechanics, where starting from Newton's equations of motion, which are both unnecessarily clumsy and also dependent on the system of co-ordinates used, we end by the assertion that all mechanics is included in the condition that a certain integral shall have a stationary value for the true solution of any problem. In statics we are familiar with this as the Principle of Virtual Work : in dynamics it appears as the Principle of least Action (Maupertuis), or of least Constraint (Gauss) : in optics as the Principle of least Time (Fermat). There are similar applications in Quantum Theory and Relativity.

The subject is as inherently beautiful as any branch of mathematics— which is saying a lot—and one of the greatest attractions of this book lies in the evocation of this beauty. Here, despite frequent summaries of each section, enclosed in black rectangles and looking for all the world like tombstone tablets, there is a sense of joy and even of ~~purpose~~ in the unfolding of the story. Here is no examination-book, about   ~~...~~tions on tops and

gyroscopes, and continually asking : what use is this technique for solving problems ? It is not unfair to say that this is one of those relatively rare books that are suitable for maturer minds, intent to appreciate the living pattern of mathematics. It is not primarily for the expert, since all the necessary previous knowledge is nothing more than the partial differentiation of Stokes' and Green's theorems. Those who read this book—alas ! that devaluation makes its price so high—will most certainly enjoy it ; and they will quite possibly end by being convinced, in the words of the author, that the development of Variational Principles represents " a magnificent chapter in the evolution of human thought."

It is hard to cavil at such a nice book. But it would have been even more attractive had it not suffered from an almost complete omission of Relativity theory and Quantum theory, in both of which Variational processes play a quite fundamental rôle.

<div align="right">C. A. COULSON.</div>

University Mathematics. By JOSEPH BLAKEY, Ph.D. [Pp. viii + 527]. (London and Glasgow : Blackie & Son, Ltd., 1949. 25s. net.)

THIS book is intended to give, in one volume, all the pure mathematics required for a General degree in science ; and it will be agreed that there is need for such a comprehensive textbook. The author has selected his topics with care, and it is fair to say that he has included the important things and avoided irrelevancies. In the detailed execution of his programme, however, he has been much less successful, and the treatment is often inadequate and sometimes dangerously misleading. While the kind of rigour that is demanded in Honours mathematics would be quite out of place in a course for science students, and while it is right in a book like this to appeal freely to geometrical intuition, there is no justification for sacrifice of accuracy or clarity. Subtle distinctions need not be made ; but whatever discussion is entered into must be clear and convincing at its level, and when a new idea is brought in the student must see a reason for introducing it.

A few examples will indicate the nature of the shortcomings to which exception is taken. On page 2 an expansion for $(a + x)^n$ is assumed " for all rational values of n," and only afterwards is the question of its validity touched upon. The function $\sinh x$ is defined as $\frac{1}{2}(e^x - e^{-x})$ " with x taken in *radians*, i.e. a pure number " (page 32). On page 263 we find a classification of conics according to eccentricity, with the values $e = 0$ and $e = \infty$ given, without explanation, for the circle and the pair of lines—eccentricity having been defined in terms of the focus-directrix property. Finally, on page 430 moments are taken about a plane.

Mr. Blakey's book, then, is quite well arranged, and the second half is considerably better than the first ; but its slipshod character will not help to improve the quality of the work done by science students. Nor is it helpful to the many educationalists who are so seriously worried by the prevalence of illiteracy and lack of precision in the use of English when a university textbook has as the heading of one of its sections " Integration considered as an area."

<div align="right">G. T. K.</div>

PHYSICS

Mechanics : Statics and Dynamics. By MERIT SCOTT. [Pp. xii + 394, with 251 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 38s. 6d. net.)

ACCORDING to the author's preface, this book is intended primarily as a text-book for a University course of about Intermediate or first-year standard. It should, in fact, serve this purpose very well, for first-year students of Mathematics as well as students of Physics or Engineering.

Part I of the book deals with Statics and begins with two chapters on vectors and vector algebra, with a brief treatment of vector analysis. Vector methods are, in fact, frequently applied throughout the book. The ground covered in Part I is about the same as in existing textbooks at this level, but there is a fuller treatment of moments and products of inertia and an excellent chapter on Elasticity, giving the analysis of stress and strain. The chapter on Structures and Beams includes Euler's theory of struts and a brief treatment of tension webs.

Part II deals with Dynamics and opens with a chapter on Kinematics, treated by vector methods. Here again the scope of this part of the book compares well with that of existing textbooks. The last chapter, however, deals with three-dimensional motion and the equations of motion of a rigid body. There is a brief discussion of the steady motion of a top and of the formulation of the equations of small oscillations of an aircraft about steady horizontal flight.

The presentation is clear throughout the book, and there is a judicious selection of the subject matter in the various chapters. Each chapter is followed by a good number of examples, many of them numerical. There is an adequate index and also a list of symbols used in the book. The standard maintained in the printing both of the text and of the diagrams is uniformly high and enhances the value of the book.   L. A. W.

Applied Mechanics : Statics. By GEORGE W. HOUSNER and DONALD E. HUDSON. [Pp. x + 220, with 355 figures.] (New York : D. Van Nostrand Co., Inc. ; London : Macmillan & Co., Ltd., 1949. $3.00 or 15s. net.)

ONE may well be forgiven for wondering why another book should be added to the already long list of elementary textbooks on Statics. In fact the authors of this book admit in Appendix I that " the subjects discussed in this book are treated in a very large number of books " and proceed to give a list of fifteen of them. It is only natural that students prefer textbooks written by their own teachers and, presumably with this in mind, the authors were inspired to write this one.

Although primarily intended for Intermediate students, the book does in fact go some way beyond that standard in dealing with such subjects as Dot and Cross Products of Vectors, Principles of Virtual Displacements, Stability of Floating Bodies, the Catenary, etc.

In the text and also in many worked examples, particular emphasis has rightly been laid on the importance of the " Isolation of Mechanical Systems " and the careful drawing of " Free-body Diagrams." So often, students will just not take the trouble to draw these diagrams and consequently fail to solve the particular problem.

Great care is taken in Chap. IV to distinguish between Centres of Gravity, Centres of Mass, and Centroids of lengths, areas, and volumes. Unfortunately the same careful distinction is not made between Moment of Inertia (*i.e.* second moment of a *Mass*) and Second Moment of an *Area*. This invariably leads to confusion between the corresponding units, namely lb. ft.^{2} and ft.^{4} respectively. The theorems of Pappus involve important principles, and their proof, together with some worked examples on their application, could with advantage be included. In the sections devoted to Hydrostatics the principles are very clearly expounded. No reference is made, however, to the problem of calculating the thrust on the curved surface of a vessel due to a fluid *inside* it. The normal student would find some difficulty in following the steps leading to the equation for the metacentric height.

Excellent diagrams, and a great variety of worked examples ; tables of Centroids, Moments and Products of Inertia, together with squares of radii of gyration for plane and solid figures ; all these combine to make an attractive and very useful addition to the list of textbooks on Statics.

<div align="right">F. C. H.</div>

A General Kinetic Theory of Liquids. By M. BORN, F.R.S., and H. S. GREEN. [Pp. viii + 98, with 2 figures.] (Cambridge : at the University Press, 1949. 10s. 6d. net.)

THIS book is a collection of five papers of a series on the general kinetic theory of liquids and another paper on the kinetic basis of thermodynamics which appeared in the *Proc. Roy. Soc.* in 1947–48. These papers constitute a most interesting new and systematic approach to the theory of the liquid state, where development has been lagging behind that of the theory of gases and solids, because on the one hand the simplifying assumptions of the kinetic theory of gases cannot be applied to a dense assembly of molecules and on the other hand the methods so successfully used in the theory of solids can only be applied to the treatment of systems with a high spatial order.

The new method consists essentially in the introduction of sets of d stribution functions for singlets, doublets, triplets, etc., of molecules in an assembly, and the setting up of differential equations for them which are generalisations of the Boltzmann equation of the kinetic theory of gases. First, the equilibrium properties of fluids are treated on this basis ; in particular, explicit formulæ for the thermodynamic functions and the equation of state are derived, and it is shown that the latter has two " branches " which can be identified with the gaseous and the liquid states respectively. Next, the theory is applied to the dynamics of fluids, and here the authors endeavour not only to derive the thermo-mechanical equations of motion but also rigorous expressions for the coefficients of viscosity and thermal conduction.

So far the theory is founded entirely on classical mechanics ; the next step consists in replacing classical by quantum mechanics, which is achieved by translating the classical formalism into the quantum formalism in the usual way, *i.e.* by replacing functions of the co-ordinates and velocities of the particles by operators. A most important fact is revealed in this way, namely that in quantum hydrodynamics the thermodynamically defined quantities " temperature " and " pressure " must be replaced by " dynamically " defined quantities which are not identical with the former.

Chap. V constitutes the first attempt to derive the laws of thermodynamics from quantum mechanics alone. A proof of a generalised H-theorem is given

rom which the second law of thermodynamics can be deduced. The first law, however, does not hold generally in the usual sense in liquids, as under extreme quantum conditions, *i.e.* at very low temperatures, no clear distinction between " thermal movement " and macroscopic mechanical movement of the system is possible, the former actually being of macroscopic order of magnitude. This and the fact that under such circumstances the difference between ordinary and dynamic temperature and pressure becomes very pronounced probably provide the clues for the understanding of the many remarkable properties of liquid He II, the only " quantum liquid " known so far. Whether, however, the explanations suggested for those phenomena on the basis of the theory are compatible with the experimental facts remains to be seen.

The book provides most stimulating reading for all who are interested in the kinetic theory of matter and the kinetic foundation of thermodynamics, and will be indispensable to every research worker in this field.

R. FÜRTH.

Molecules in Motion. By T. G. COWLING, M.A., D.Phil., F.R.S. [Pp. 183, with 27 figures.] (London : Hutchinson's University Library, 1950. 7s. 6d. net.)

" NATURE cannot be understood simply from mathematical calculations. The proper line of approach is neither that of the mathematician working without contact with experiment, nor that of the experimenter carrying out measurements to a steadily increasing degree of accuracy without enlightenment as to their meaning, but a middle course in which theorist and experimenter co-operate in building up a fruitful conception of the way in which nature works." This quotation is from the author's introduction, and the book itself is a tribute to the skill with which Prof. Cowling has succeeded in providing a readable survey of those properties of a gas which can be explained by assuming that it consists of molecules in motion. Some knowledge of elementary physics, mechanics and chemistry is assumed, and, where mathematical argument is employed, the ideas are explained simply, without detailed proofs which are beyond the scope of the book.

The earlier chapters are historical. They include the philosophy of Aristotle and the work of Boyle, Dalton, Avogadro, Clausius and Joule. Following chapters discuss properties of a gas, such as free path, viscosity, heat conductivity, diffusion, the forces between molecules and their internal energy. Maxwell's derivation of his velocity-distribution is given, together with a simplified statistical proof, and this is followed by an interesting chapter on the atmosphere. Finally, a few properties of ions and electrons, as they affect the conduction of electricity in gases, are briefly reviewed.

The volume is well illustrated and produced, and provides the general reader with an interesting account of the kinetic theory of gases. In conclusion, the term "standard " might replace "normal " when referring to standard temperature and pressure.

F. H. NEWMAN.

Dynamics of Real Fluids. By E. G. RICHARDSON, B.A., Ph.D., D.Sc. [Pp. viii + 144, with 96 figures, including 2 plates.] (London : Edward Arnold & Co., 1950. 21s. net.)

DR. RICHARDSON'S researches and publications on acoustics and hydrodynamics are now well known and the appearance of his latest book on

Dynamics of Real Fluids will be welcomed. Progress in fluid dynamics during recent years and its applications in supersonic flight, jet propulsion and so on make this book a valuable addition to such works as Lamb's *Hydrodynamics* and *Modern Developments in Fluid Dynamics* (edited by Prof. Goldstein).

Of course the relevant word in the title of the book is "real." It was to be anticipated therefore that the opening chapter would deal with classical dynamics of "ideal" fluids, the reader being subsequently introduced to the study of fluids which depart in various ways from the ideal. In this chapter reference is made also to potential flow and to flow in liquids where viscosity is large compared with inertia—the forces on an obstacle in a very viscous fluid are deduced. The technique of measurement of fluid motion is also dealt with.

Much consideration is given to fluids of small viscosity, Prandtl's theory of vortices and boundary layer theory. Examples are given of the use of hot wire anemometers in the study of vortex flow and to investigate boundary layer conditions around obstacles immersed in a flowing fluid. In particular, the boundary layers over flat plates, in pipes and near rotating cylinders are considered, and theory compared with experiment. Attempts are described to control the boundary layer by artificial adjustment of the pressure or flow in local areas around the obstacle. Reference is also made to periodic boundary layers where alternating flow is superposed on direct flow, and to circulations of solid particles in stationary sound waves in air. In dealing with the flow of compressible fluids an interesting discussion is given on shock waves and supersonic jets. A chapter, dealing with fluids with a temperature gradient, refers to natural and forced convection in fluid streams passing over flat or cylindrical heated surfaces, leading to a discussion of the behaviour of the hot wire anemometer. Convection at super-sonic speeds receives brief attention. Gravity and surface waves are considered from the theoretical aspect, followed by a description of methods of measuring wave-height and swell and pressure on the sea bed. An interesting and important discussion follows on impact forces and cavity formation when a solid body is projected at high speed into a liquid. The theoretical and experimental aspects of the break up of liquid jets and the formation and fall of drops are not only of interest academically but have important practical applications. The concluding chapters deal with fluids of anomalous viscosity, sols and gels, suspensions in turbulent fluids, emulsions and thixotropy.

Dr. Richardson gives much information arising from his own researches, *e.g.* on vortices, boundary layers, turbulence, erosion, hot wire anemometry, formation and fall of drops, sea waves, emulsions and gels, etc. Although it does not claim to be a complete treatise, the book is nevertheless full of interest and provides a very useful summary of recent work in the field of dynamics of fluids.

A. B. WOOD.

The Measurement of Air Flow. By E. OWER, B.Sc., A.C.G.I., F.R.Ae.S. Third edition. [Pp. viii + 293, with 101 figures.] (London : Chapman & Hall, Ltd., 1949. 30s. net.)

A THIRD edition of this well-established textbook is welcome. That it should have been called for is evidence that in the comparatively limited field of applied physics with which it deals it is regarded as pre-eminent. Certainly

any worker would be ill-advised who started a research in aerodynamics without a knowledge of the instruments and their theory which is here displayed. The author is apparently worried lest he should have put too much of his own research into the first two editions and has tried to correct the "fault," but we could ill dispense with a knowledge of his researches in this field, particularly of that which made the vane anemometer a precision tool.

A good deal of the new matter is devoted to refinements in the use of the pitot-static tube, particularly when used in turbulent or pulsating flow ; and to the plate-orifice, for which new standard coefficients are quoted ; while there is a lengthy description of modern sensitive manometers. Only in the chapter on flow measurement by the cooling of hot-bodies would one like to see a more up-to-date treatment. The hot-wire anemometer has become the instrument *par excellence* for exploring the details of a flow system and for studying fluctuating flow, so that it is a pity to find the state of this branch of aerodynamics described as it existed twenty years ago.

<div align="right">E. G. R.</div>

Streamline Flow. By H. F. P. PURDAY, B.Sc., A.C.G.I., A.M.I.Mech.E. [Pp. viii + 185, with 53 figures.] (London : Constable & Co., Ltd., 1949. 18*s*. net.)

THIS book is written by an engineer by profession - the author is a chief designer of the higher speed Diesel engines -- but a mathematician by inclination. The book does not pretend to be a technical treatise on the subject of its title, but more of an introduction to the mathematics of hydrodynamics and the flow of heat. As the author points out, " the use of Gamma functions, Fourier series, orthogonal functions, and the integration of differential equations by series and by numerical methods " are illustrated by examples drawn from these two fields of applied mathematics.

Most chapters have a section at the end in which are worked out some examples of a definitely practical and utilitarian character. It is difficult, however, to see what purpose is served in the section on viscous flow in pipes by the approximate methods evolved for the square and rectangular section tubes. The exact treatment of these is certainly simple enough to come within the scope of the book, involving as it does only an elementary application of a Fourier series to a boundary problem, and the reduction of this to an approximate form for $a/b > 3$ is relatively simple and direct. In any case it would have been better to replace the index n in the approximating function $u = u_m(1 - y^n/a^n)(1 - z^2/b^2)$ for the rectangular section by $2n$, since the form given may make u complex when y is negative, and the reader may well be puzzled as to why such a non-physical approximation gives anything approaching the accepted values of the flow coefficient sought.

It is not until the last chapter that there is a statement of the Napier-Stokes equations and consequently the development of the argument is often by means of dimensional analysis and may give the student a false impression of the way in which the theory has evolved. Most of the common dimensionless groups have originated from the strict mathematical equations and the juxtaposition of variables has not been guessed by a type of prevision. There seems to be an unfortunate tendency to assume that, for engineering purposes, it can be assumed that the function of a dimensionless number is necessarily approximated by using only one term in a power series. Prandtl, in his relation between heat transfer and fluid flow, showed that this was not

the case. The simple power function of the Prandtl number used in the Nusselt equation for heat transfer in forced convection of fluids in pipes is only an approximation over a limited range, and is incorrect outside this range.

Much has been said on the mathematical theory of lubrication, but it still remains more or less an empirical art. The experimental technique and method of reporting results developed by Wilson and Barnard in 1922 still gives a better picture of what is happening than the Petroff equation, which, on analysis, seems to be a very complicated way of saying very little.

M. B. D. AND A. C. S.

Engineering Developments in the Gaseous Diffusion Process. Edited by MANSON BENEDICT and CLARKE WILLIAMS. [Pp. xx + 129, with 45 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 11s. net.)

THIS volume is one of the National Nuclear Energy Series now being prepared as a record of the research work carried out during the war under the Manhattan Project and the Atomic Energy Commission ; it describes some of the more important problems met with in the design and construction of the gas diffusion plants for the separation of uranium isotopes and gives an account of the new procedures and auxiliary instruments which were found necessary in dealing with them.

Whilst many of the instruments and devices described were developed to meet the special requirements of isotope separation, they have in general a much wider application to chemical engineering problems ; and it is, therefore, to be regretted that a more detailed description of them has not been made available. As an example we may refer to the account of the New Developments in Vacuum Engineering contained in Chap. 5. In the gaseous diffusion plant a greater degree of tightness was required than had ever before been achieved in any commercial plant ; and one of the major engineering problems connected with the project was the development of highly sensitive and speedy methods of leak detection. These are described in some detail, but no account is given of the equally important techniques by which joints and glands are made and degassing is effected.

The subject matter of the book is arranged in four parts : Part I—Special Plant Instruments and Devices ; Part II—Vacuum Engineering ; Part III—Development of Heat Transfer Equipment ; and Part IV—Absorption of Uranium Hexafluoride and Fluorine. Each section contains a statement of the problem, a brief discussion of the underlying theory, and a summary of experimental data and operational results.

The book is illustrated by a number of detailed drawings and photographs of plant and apparatus, and each section includes a short bibliography.

D. M. N.

Physics. By C. L. BOLTZ, B.Sc. [Pp. 384, with frontispiece and 115 figures.] (London : George G. Harrap & Co., Ltd., 1950. 10s. 6d. net.)

THIS is the fifth of Harrap's " Torch " popular text-books on scientific subjects and is written by the general editor of the series. In it, in a general qualitative way, the author sets out to provide the interested layman with

some conception of the work of the physicist and of the manner in which the body of knowledge called physics has been acquired.

The eager reader of this book will probably be surprised to discover that physics appears to be largely a study of optics (160 pp.) with subsidiary interests in the phenomena of heat (48 pp.), properties of matter (90 pp.), and sound (65 pp.). Magnetism, electricity (which forms the subject matter of another of the Torch books—also by Mr. Boltz), atomics, etc., find no place in the book, and this is likely to induce a state of puzzled bewilderment in the reader, in whose mind there has doubtless crystallised a somewhat different picture of the physicist in view of the many recent reports of his activities in the popular press and elsewhere. The reader might also be irritated at having to cope with Ångström units, microns, sines, radians, etc., without previous explanation or definition, and he would certainly be puzzled by the intrusion of the altogether irrelevant jumble of mathematical symbolism on p. 85.

Within the limited scope of the book there is, however, much that will interest him, and certainly the young student of physics will derive much satisfaction and profit from the well-developed historical presentation given throughout the book, as well as from the excellent accounts of such topics as the Young-Helmholtz trichromatic theory of colour vision, the liquid state, acoustics of buildings, etc.

The book is written in a stimulating and forthright style, although the present reader found the illustrations rather unexciting. Nevertheless, in spite of the preceding criticisms, there is much to recommend this volume to a wide range of readers.

F. Tyler.

Practical Physics. By Sir Cyril Ashford, K.B.E., C.B., M.V.O., Hon. LL.D., M.A. [Pp. xii + 173, with 61 figures.] (Cambridge : at the University Press, 1950. 10s. 6d.)

This is an unusual book. Of its fifty experiments—seventeen in mechanics, sixteen in light, three in heat, thirteen in current electricity, one in magnetism and none in sound—not more than about eight would appear in a book designed to describe experiments to illustrate, and to accompany, a normal course of classwork and, of these few, most are here presented with some kind of unfamiliarity. Teachers of physics are continually trying to give their work a valuable flexibility and variety and some of the novelties of this book might well be used to this end. The author's sub-title, " A Collection of Experiments for Upper Forms of Schools and Colleges together with the Relevant Theory," indicates that he proposes its adoption as it stands, and many science masters may well wish that their time-table tyranny could be sufficiently lessened to permit some at least of their senior pupils to experiment on the independent lines here suggested. To others it will be a serious objection that, generally speaking, the experiments deal with properties with which the pupils' usual class course is not much concerned, so that the mathematical development of the relevant theory is unfamiliar and by no means simple.

To write a school book of practical physics which arouses discussion is no small achievement and that it was written about a number of tests which have already been set in the Cambridge Higher School Certificate examination is proof that it is practical in the more popular sense.

One or two small points call for notice. The index might well be increased to a useful length and it is refreshing to meet three different sign conventions in one book.

<div align="right">V. H. L. S.</div>

Heat. By M. NELKON, M.Sc., A.K.C. [Pp. viii + 240, with 89 figures.] (London and Glasgow : Blackie & Son, Ltd., 1949. 9s. net.)

A WELCOME feature of Mr. Nelkon's little book on Heat is that it is really intended for H.S.C. and Intermediate students. It makes no pretence to appeal to scholarship candidates or even general degree students. Indeed, if anything, it is in parts a little too elementary, but, presumably, the author's wide experience as a teacher has convinced him that this is a good fault.

The book deals with fundamental principles. These are on the whole clearly discussed and are in no way obscured by masses of detail. There is at the ends of chapters an abundance of questions, including many from the various examining bodies. Representative numerical examples are worked out in the text. Throughout emphasis is laid upon units.

Some of the errors that occur are surprising, e.g. that a knowledge of the pressure as well as the volume and temperature is required to specify the state of a given mass of gas (p. 55), and that the critical pressure of a substance is its pressure at the critical temperature (p. 183). Other errors are more subtle, e.g., in the derivation of the calorimetric cooling correction, the ordinate separating the two relevant areas under the temperature/time curve is drawn from the peak of the curve (p. 94).

Finally, it should be pointed out that there is no chapter on certain aspects of meteorological physics.

<div align="right">J. W. F.</div>

Colours and How We See Them. By H. HARTRIDGE, M.A., M.D., Sc.D., M.R.C.P., F.R.S. [Pp. xii + 158, with 12 coloured plates and 39 figures.] (London : G. Bell & Sons, Ltd., 1949. 15s. net.)

THE Christmas Lectures given each year to boys and girls at the Royal Institution have been responsible for a number of popular scientific books, and we have here a volume based on the lectures given by Prof. Hartridge in 1946. He chose a fascinating subject for his lectures and the book shows what a wide field of natural phenomena reveal some colour effect or another. Dyes, pigments, the eye, haloes, contrast, dichroism, illusions, spectra, interference and many other topics all find a place, with numerous coloured illustrations to show the kind of effect that can be observed. Inevitably, in a fairly short book, in which so many different items are mentioned, none can be dealt with in much detail. In general, however, sufficient information is given to arouse interest in the subject and to whet the reader's appetite for more. Since stimulation of interest is naturally one of the chief aims of this type of lecture course, Prof. Hartridge can certainly claim to have achieved his purpose.

<div align="right">W. D. W.</div>

Sight, Light and Efficiency. By H. C. WESTON. [Pp. xiv + 313, with 132 figures, including 13 in colour.] (London : H. K. Lewis & Co., Ltd., 1949. 42s. net.)

DURING the last two or three decades increasing attention has been paid both to the preservation of sight and to the provision of better industrial lighting.

It has not been appreciated, however, that the proper use of the eye in industry demands the co-operation of personnel officers, ophthalmologists, lighting engineers and the operatives themselves. Mr. Weston's valuable book, whilst giving much new and original data, serves also to co-ordinate all previous work in a field in which the author is himself so distinguished a worker.

After a descriptive treatment of the mechanism of vision, Mr. Weston reviews the various kinds of eyestrain, showing how they are caused, how they can be corrected, and how the various classes of sufferer can best be employed in industry. This leads to a consideration of visual tasks in general and their facilitation by such means as optical aids, the treatment of work objects, and the provision of the right quantity and quality of illumination. To the lighting engineer this book should give a clearer appreciation of the factors which underlie the rule-of-thumb methods, such as illumination charts and lighting codes, which are so widely used in the profession. The author urges upon the industrialist the necessity for providing suitable seeing conditions for all visual tasks, and for establishing simple sight tests for employees so that their visual capacity can be used to mutual advantage.

The book is lavishly illustrated and well produced, the few misprints and errors being so obvious that they are not likely to mislead ; though in the treatment of daylight factor on pp. 152–3 it would perhaps be advisable to include the usual proviso regarding the exclusion of direct sunlight in making the outdoor measurement of illumination intensity.

The text is closely written ; so closely, in fact, that some paragraphs are rather involved. Yet the whole book repays a careful study by all who are concerned in industrial welfare, in the allocation of manual tasks, and in the provision of natural and artificial lighting for industrial premises.

H. H.

Spectroscopic Properties of Uranium Compounds. By G. H. DIEKE and A. B. F. DUNCAN. National Nuclear Energy Series, Vol. III –2. [Pp. xviii + 290, with 25 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 23s. 6d. net.)

THE title implies a specialised study, but this book covers a field of wide general interest full of significance in the theory of the crystalline state. It contains in detailed appendices quantitative measurements of the absorption and fluorescence spectra of a number of uranyl and double uranyl salts in the solid state, and the discussion centres round these data. Most of them were obtained at low enough temperatures and high enough dispersion and resolution to appear as resolved electronic-vibrational bands, so that the subject takes on some of the complexity and significance of molecular spectra. The fluorescence spectra are relatively simple, as they appear to originate from a single excited state, and they are due to the uranyl ion ; this fact forms a coherent theme throughout Part I of the book. The identification of vibrational levels thus becomes of great value for detailed study of the perturbations due to the crystalline field and to interaction with other groups and is achieved both by systematic comparison of related compounds and by the skilful employment of modern resources like isotopic replacement ; even the uranium shifts have been resolved and may become the basis of important analytical procedures or of photochemical separation. The authors make quite clear that they and their co-workers have set the stage for much future research rather than finishing the act—for example, in polarisation measure-

ments which have so far been hampered in many instances by the technical difficulty of preparing good single-crystal specimens—but the beginning is impressive and is discussed with good sense from a wide spectroscopic experience.

Chapter II usefully gives a background of X-ray crystallographic data on $Rb(UO_2)(NO_3)_3$ and discusses the linearity of the UO_2 ion. In view of the central importance of this group, it is unfortunate that the linearity or otherwise, and the exact $U - O$ distance, could not be finally established.

Part I is well illustrated with spectrograms, but the general reader will wish that a wavelength scale had been included. Part II deals briefly with problems of synthesis and crystal growth and contains much new material.

G. E. PRINGLE.

Practical Microscopy. By L. C. MARTIN, D.Sc., A.R.C.S., D.I.C., and B. K. JOHNSON, D.I.C. Second edition. [Pp. x + 124, with frontispiece and 90 figures, including 10 plates.] (London and Glasgow : Blackie & Son, Ltd., 1949. 6s. 6d. net.)

THE new edition of this well-known work follows the same lines as its predecessor, although it has been brought up to date by the inclusion of a chapter on the electron microscope and a section on phase contrast illumination.

Some users of the book will probably complain at its brevity and this is a criticism which may well be advanced against some of the sections. For example, it seems clearly impracticable to deal with the preparation of specimens for the microscope and to include the preparation of metal specimens and the use of hæmacytometers in just over nine small pages, and it is difficult to avoid the feeling that this space could have been better devoted to amplification of certain other sections. Nevertheless, the book serves well as a practical introduction to the technique of modern microscopy, and includes chapters on photomicrography, the metallurgical microscope and ultra-violet microscopy. Moreover, the authors have not neglected the optical principles involved, while they also deal with the physical limitations of the apparatus which they describe.

F. W. J.

Sound Absorbing Materials. By C. ZWIKKER and C. W. KOSTEN. [Pp. x + 174, with 92 figures.] (Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. 22s. 6d. net.)

THE origin of this book was a text written by Dr. Zwikker during the war, but delays in publication have made it necessary to re-write almost the whole of it—a task he entrusted to Dr. Kosten.

The first part of the book is concerned with the theoretical treatment of pervious layers, wherein a useful concept called "structure factor," determining the relation between the solid and fluid portions of the absorbent, is introduced. Experimental results for plasters are given to show how the complex stiffness and density components may be deduced. There then follows the theory of elastic absorbents.

The remainder of the book is taken up with the tube method for measuring the acoustic impedance of specimens and the absorption by resonators. There is perhaps too much attention paid to the practically unimportant case of normal incidence, the effect of obliquity being relegated to a few pages at the end.

The authors are probably correct in stating that there is no book with a similar aim in existence, and it should accordingly be on the shelves of all who are concerned with technical acoustics.

E. G. R.

Cosmic Ray Physics. By D. J. X. MONTGOMERY. [Pp. viii + 370, with 15 plates and 97 figures.] (Princeton, N.J. : Princeton University Press ; London : Oxford University Press, 1949. 40s. net.)

DR. MONTGOMERY'S book is particularly welcome because he writes with a background of active post-war research both in America and in England. Moreover, he has also close acquaintance with the important work carried out in recent years by the school of Marcel Schein.

Particular attention must be drawn to the illustrations. The plates are well chosen and admirably reproduced, and their value has been further increased by detailed and informative legends, giving both the interpretation and also, when appropriate, the detailed estimates of momentum, ionisation, etc., which allow the reader to follow the arguments involved in the process. The text figures are in many cases treated in the same way.

In the text, Dr. Montgomery has properly resisted the temptation to modify the emphasis of the whole work to the latest data, and the π meson accordingly enters only to a minor degree. Instead, the main lines of work yielding results up to 1948 are treated critically with extensive documentation. The two most important chapters cover respectively the Hard Component (including penetrating shower phenomena), and the Soft Component, while other chapters deal with Experimental Methods, Intensity (Geophysical Data) and Heavy Particles (Protons, Stars). An early chapter, whose pages bear the quite misleading short title " Cosmic Ray Apparatus," provides a useful summary of such topics as ionisation, diffusion of ions, recombination, motion in magnetic field and shower theory, and finally, in excellently chosen Appendices, an outline of the Störmer theory, the Arley cascade data, and the Princeton range-energy and range-momentum tables are included.

This is essentially a book for the specialist, but the general reader prepared to follow the development of a subject in rapid transition will find here a particularly well-balanced account of cosmic ray physics up to the time of writing.

J. G. WILSON.

Magnetism. By D. SHOENBERG, Ph.D. [Pp. x + 216, with 8 plates and 56 figures.] (London : Sigma Books, Ltd., 1949. 10s. 6d. net.)

IN this little book of some 200 pages Dr. Shoenberg has succeeded in giving an up-to-date picture of all the main related electric and magnetic phenomena. He has not attempted to avoid technical terms, but a convenient glossary provided at the end of the book enables the reader to refresh his memory in the easiest possible manner if he finds it difficult to grasp the meaning of a term, like susceptibility, at a first encounter. Moreover, even simple mathematical statements are employed only when they really lessen the effort required of the reader in his attempts to grasp unfamiliar physical facts.

It is not easy to write a book of this kind without some ambiguity or error, brought about by the severe condensing of so much scientific and technological material in so small a volume. Nevertheless, the book is surprisingly free from such faults, both in the treatment of modern theories and

in descriptions of practical applications. Adequate attention has been paid to the theoretical aspects of diamagnetism, paramagnetism and ferromagnetism and to the features one would expect to find in a magnetic laboratory. The author has, however, omitted to use or mention the oersted as the international unit of field intensity. Many will no doubt continue to share his apparent dislike of the term, but it has probably come to stay. However, its omission should not detract from the welcome one accords to an eminently readable book, to which the general public, or the student in need of what is termed general education, may turn with much profit.

L. F. B.

Electricity in the Service of Man. By SYDNEY G. STARLING, B.Sc., A.R.C.Sc., F.Inst.P. Revised by H. J. GRAY, M.Sc., LL.B., A.Inst.P. [Pp. x + 255, with 140 figures, including 8 plates.] (London, New York, Toronto : Longmans, Green & Co., 1949. 12s. 6d. net.)

THIS book was originally written by Mr. Starling and published in 1922, and was " designed to present to the general reader and to the student in other branches of science an appreciation of the subject of electricity as it appears to the physicist of to-day." Mr. Starling included, as in his other books, in the subject of electricity some parts of what we should now call atomic and nuclear physics. To-day, electricity, especially when extended in this way, appears to the professional physicist a very different subject from that of twenty-seven years ago, not only in respect of numerous detailed changes and additions, but in its whole balance. To revise Mr. Starling's original book to give a true picture of the present scene is indeed a major task.

The reader's hopes are raised by the statement in Mr. Gray's preface " This book . . . has been revised throughout and brought up-to-date. Some descriptions of the most recent developments of physics and their applications have been added. Cathode ray tubes and their use in television and radar and the general study of transient phenomena which can be converted into electrical impulses have been described at some length and some modern uses of photo-electric cells are given." The revision is, nevertheless, most disappointing, and the book has a distinctly old-fashioned air. No thermionic valve later or more complex than the triode is even mentioned. The cathode ray tube illustrated and described is the gas-focused type now almost entirely superseded by those using electron-optical focusing. The description of television occupies only a page and a half, and is confined to the transmission of pictures already recorded on plate or film. The description (" at some length ") of radar is confined to 60 *words* mentioning only the device known to many as H_2S. Though the photo-emissive cell is mentioned in addition to the photoconductive one, the much-used photovoltaic cell is not. The whole advance in atomic and nuclear physics (including the atomic bomb) since 1922 is described in about two pages and one plate ; the whole balance is wrong. The cloud chamber photographs reproduced all date from C. T. R. Wilson, and, while very beautiful, do not represent the scope and achievements of modern work with the chamber.

Throughout the book there are a number of incorrect and misleading statements, e.g. " (semiconductors) are never used for electrical purposes " (p. 16), " the filament (of a diode valve is) either of carbon or tungsten " (p. 173) and others too long to quote.

Thus the book does not now succeed in its object in presenting the subject

as it appears to the physicist of today, though it is still useful for the descriptions of earlier work and applications. Even in its present form, a guide to further reading would have been a great help.

F. A. V.

Ionization Chambers and Counters : Experimental Techniques. By B. B. ROSSI and H. H. STAUB. [Pp. xviii + 243, with 140 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 19s. 6d. net.)

THIS book constitutes Vol. 2 of Division 5 of the declassified portion of the National Nuclear Energy Series which, when completed, is expected to consist of over 60 volumes. The difficulties inherent in transmitting information on nuclear physics are fully admitted by the Editorial Board and are set out in lengthy prefaces and forewords. The present effort constitutes a useful laboratory manual, in spite of the fact that many of the techniques and circuits are now well known and some are even obsolescent.

The first chapter contains an account of the behaviour of free electrons and ions in gases. This is followed by chapters on the operation of ionisation chambers with constant ionisation and with variable ionisation, and an account of gas amplification. A description of various detectors for β-rays, γ-rays, X-rays, neutrons and fission products completes the compendium. The experimental tips will prove of use to those undertaking constructional work on ionisation chambers. Perhaps the most valuable part of the book is the collection of numerous graphs illustrating operational data.

F. C. CHAMPION.

Atomic Energy Year Book. Edited by JOHN TUTIN, D.Sc. [Pp. xx + 237, with frontispiece and 23 figures.] (London : Temple Press, Ltd., 1949. 21s. net.)

ACCORDING to the preface this book is intended to supply a convenient means whereby the industrialist and technician may have at hand reasonably up-to-date information on the development of atomic energy. Its emphasis is away from atomic warfare and towards the civil exploitation of atomic physics ; the index contains no reference to bombs—whether atomic or hydrogen.

The range of the *Year Book* may be gauged from the titles of its fourteen chapters—History of Nuclear Science ; The First Reactor ; Atomic Energy Reactors ; By-products of Atomic Energy ; Some Economic Consequences of Atomic Energy ; Ship Propulsion by Atomic Energy ; Survey of Atomic Energy Development (in U.S.A., Canada, Europe, etc.) ; Legal Aspects ; Design of Radiation Laboratories and Organisation of Safety Technique ; Human Welfare and Isotopes ; Medical Research (Laboratory Reports on Applications of Isotopes) ; Radioisotopes ; Research Frontiers ; International Control of Atomic Energy.

It is perhaps inevitable that in a compilation such as this, in which an attempt is made to cater for various types of enquirer, the level and amount of previous knowledge assumed by the reader vary over wide limits. Thus, while Chap. II gives a journalistic account of the First Reactor, Chap. XIII brings in the spin of the neutrino and an appendix gives a Table of Nuclear Spin from Atomic Number 1 to At. No. 83. Similarly *capture cross section*

mentioned on p. 17 is not defined until p. 210 is reached, and the *Rep* and *Rem* units are defined in terms of the " r " (rontgen) which is itself not defined. Nevertheless, the editor is to be congratulated on producing a useful and interesting book, of wide appeal to persons possessing a scientific background.

It should be especially valuable to those contemplating the use of radioisotopes as " tracers " in medical and biological research, and is commended to the notice of hospital physicists and their radiological colleagues.

F. L. H.

A Symposium on Electronics in Research and Industry. Edited by A. G. PEACOCK. The Scientific Instrument Manufacturers Association of Great Britain, Ltd. [Pp. xiv + 199, with numerous figures.] (London : Chapman & Hall, Ltd., 1949. 16*s.* net.)

THE papers read at this Symposium form a miscellany and are in no way related in subject matter. Some aim to be surveys, whilst others are more limited in scope. Many, though not all, of the authors tend to describe only their own firm's products without drawing on a wider field ; one accepts this slight limitation, however, in view of the nature of the Symposium.

The first group of papers deals with electronics in research. D. J. Myna's " Electronics in Computing " forms a brief introduction to the subject and is provided with many references. " Frequency Measurements—a Review," by E. A. Rea Palmer and R. W. Darvill, though quoting much catalogue material, contains a long bibliography. R. E. Reason's " The Measurement of Small Displacements by Electrical and Electronic Methods " is one of the best reviews in the book and covers several methods. In " Measurement of Ionizing Radiations," G. Syke shows the orders of magnitude that are involved and indicates the limits to which amplifiers and detecting devices must work. W. Steckelmacher's review of " High Vacuum Gauges " will repay study showing, as it does, the types of gauges to be used for different pressure ranges. The short paper on " The Radio Sonde and Its Manufacture " by J. Foster Veevers is primarily concerned with constructional details and manufacturing procedure.

The second group is termed " Electronics in Industry." " Some Industrial Applications of Ultrasonics " by D. O. Sproule deals with an echo sounder and flaw detector. " Metal Detection in Industry " by G. S. Elphick, A. R. Woods and S. Y. Logan is of interest since such application is relatively new and not yet widely adopted. L. P. Corté, in " Sound and Vibration Measurement in Industry," limits himself in the types described, particularly on the vibration aspect. " Electronics in Spectroscopy " by F. Holmes indicates the requirements to be met by electronic apparatus for this purpose and outlines the general types used. J. Bell concludes with " Some Developments in Picture Telegraphy " in which he describes the principal features of a modern system.

A. J. MADDOCK.

Electron Microscopy : Technique and Applications. By R. W. G. WYCKOFF. [Pp. x + 248, with 202 figures.] (New York and London : Interscience Publishers, Inc., 1949. 40*s.* net.)

ALTHOUGH it is now more than ten years since electron microscopes became commercially available, there has been a lack until now of a manual of the

special experimental techniques involved in their application in research. Those works which have appeared on the physical theory and construction of the instrument have contained only brief treatments of preparative methods and little more on operating techniques. The gap has now been largely filled by the publication of two works : *The Practice of Electron Microscopy*, edited by D. G. Drummond for the Electron Microscopy Group of the Institute of Physics (Royal Microscopical Society, London, 1950), and the present volume by Wyckoff. The former confines itself almost entirely to specimen techniques, whereas the latter essays a wider treatment. It includes hints on the operation and maintenance of the electron microscope, and discusses at some length the nature and significance of its applications in biology, as well as describing the relevant specimen techniques.

The opening chapters shortly survey the principles of electron microscopy, and the construction and capabilities of the instruments at present commercially available. The following chapter on instrumental adjustment and operation contains much valuable information, but is rather compressed and may be difficult to follow unless the reader is already familiar with the type of electron microscope employed in the author's laboratory. The chief methods of specimen preparation are then described, including a variety of replica techniques for the examination of surfaces. The chapter on metal shadowing is especially complete and informative, as was to be expected of the originator of the technique.

The main directions of application of the instrument in metallurgy and biology are discussed in the second half of the book. The treatment of the former is rather shorter and less critical than is that of the latter field, reflecting the author's own preoccupation with biophysical research. No better account has appeared anywhere of the biological problems in which the electron microscope can be a valuable aid, and of the work so far carried out with it. Investigations of the structure and properties of bacteria, animal and plant viruses, fibres and tissues, are all fully described and their biophysical applications discussed. The extent of the evidence now becoming available on the macromolecular structure of biological material may come as a surprise to many among both physicists and biologists. The whole text is marked by a clarity and conciseness that might be expected of a writer describing his own field of work, but is rarely found in the result. It also shows an even rarer freedom from technological jargon, so that the second part in particular can be highly recommended to nonspecialist readers, giving as it does a fascinating account of the activities of the biophysicist in the border regions between living and inanimate matter.

V. E. C.

An Introduction to the Theory and Design of Electric Wave Filters.
By F. Scowen, B.Sc., A.Inst.P. Second edition. [Pp. xii + 188, with 71 figures.] (London : Chapman & Hall, Ltd., 1950. 18s. net.)

THIS is a revised edition of a book first published five years ago. In its new form the principal change is represented by the inclusion of Darlington's insertion-loss method of filter design, a valuable development in the technique.

After a survey of some mathematical relationships and circuit theorems particularly applicable to the solution of filter problems, the author introduces the ladder network, with special reference to constant-K sections, *m*-derivation, insertion loss and phase-shift characteristics. He then proceeds to

discuss the half-section filter for low-pass, high-pass and band-pass applications, giving practical examples of each. Lattice networks are also dealt with and their use in the design of crystal filters is considered. This is followed by a brief discussion of the limitations imposed in practice by the components of the circuit and by the interactions between them. Finally, the comparatively new procedure due to Darlington for designing filters on an insertion loss basis is surveyed and a good example of low-pass filter design based on this method is given. The book can scarcely be regarded as an introduction to the subject, nor is it really suitable for that purpose, but it is undoubtedly an excellent guide and reference for the design engineer. Anyone with knowledge of the principles and wishing to establish by calculation a filter to meet given requirements will find in this volume all the tools readily available for his purpose. The book is well produced and clearly illustrated.

H. M. BARLOW.

Recent Advances in Radio Receivers. By L. A. MOXON. [Pp. x + 183, with 91 figures.] (Cambridge : at the University Press, 1949. 18s. net.)

PREVIOUS volumes in this series of monographs on Modern Radio Technique have described the spectacular development and application of centimetre wavelength equipment. This volume is devoted to those parts of the radio receiver field in which the operation does not depend upon, although it is perhaps affected by, finite electron transit times, *i.e.* in which ordinary valves and crystal rectifiers are used. The advances described are those of the last ten years, the fifth decade of radio receiver history, and the assumption that the reader is familiar with the technique of a decade ago means that the presentation must be in some parts disjointed and descriptive rather than didactic.

Almost a half of the book is devoted to the problem of noise in receivers. There are chapters on Noise Factor, the concept that has proved so fruitful in wide-band receiver design, and on its measurement. Further chapters discuss the theory and design, in terms of this Factor, of amplifiers and mixers with low noise levels. Most of this work was initially done on the mixers and I.F. amplifiers of radar receivers, but is of quite general application. Feedback, the grounded-grid triode, and the modern high-slope pentode figure prominently in these chapters.

The author's second major topic is the performance of I.F. amplifiers and the achievement of wide frequency band with minimum distortion using the various forms of tuning, coupling, and feedback. This section is again the fruit of radar development, and has obvious relevance to television receiver technique.

The remainder of the book is a miscellaneous collection of information about trends in receiver design and what the author calls "some new circuit tricks." This miscellany certainly includes matters of general interest, but it seems out of place in a text of this kind. The chapter on circuit technique is particularly superfluous in view of the promised volume on that subject in the same series. The first two very valuable sections of the book could with advantage have been published alone under a modified title.

H. MARRIOTT.

Radio Aerials. By E. B. MOULLIN, M.A., Sc.D. International Monographs on Radio. [Pp. xii + 514, with 243 figures, including 4 plates.] (Oxford : at the Clarendon Press, 1949. 50s. net.)

THIS book is chiefly devoted to the study of aerials suitable for metre wavelengths, and contains much hitherto unpublished research, both theoretical and experimental.

The theoretical foundations are laid in the first chapter, which contains the necessary electromagnetic theory and some radiation calculations. The next chapter deals with the theory of aerial arrays and is followed by a very thorough treatment of the Vee reflector. Diffraction effects of semi-infinite sheets and the reflecting properties of wire mesh are then considered. Two chapters on diffraction by cylinders and sheets follow, and the final chapter of the theoretical part of the book deals with the single isolated aerial.

The remaining third of the book is devoted to experimental work, and is introduced by some helpful practical advice on methods and equipment for aerial measurements. Many experimental radiation patterns of Vee reflectors and parabolic reflectors are given, together with experimental investigations of edge diffraction, beam swinging, etc. The final chapter deals with end-fire, broadside, and Yagi arrays.

A most valuable feature of this part of the book is the thoroughness with which the experimental results are explained and analysed in terms of the preceding theory. The necessity of a good understanding of aerial theory before attempting serious experimental work is very clearly demonstrated.

Less satisfactory is the uncritical acceptance of the "induced e.m.f." method of calculating radiated power, with no mention of the well-known difficulty with boundary conditions. Similarly, the chapter on the isolated aerials makes brief reference to Hallén's theory, but overlooks the vital point that the near field calculated by Hallén's integral equation method does satisfy the boundary conditions.

Prof. Moullin is reluctant to regard c as a velocity, but the supporting argument that ". . . it is but the ratio of two systems of units " begs the question, and it is surely inconsistent with this interpretation of c to retain, as Prof. Moullin does, the conception of electromagnetic *waves*. The use of the rationalised M.K.S. system of units would have eliminated the foregoing erroneous dimensional argument, besides bringing the book into line with most of the recently published work in this field. It is unfortunate that the Editors' suggestion to adopt this system came too late for the conversion to be practicable.

There is no doubt, however, that this book is a valuable contribution to the literature of aerials and will appeal strongly to the aerial design engineer.

A. L. CULLEN.

Indentation Hardness Testing. By V. E. LYSAGHT. [Pp. 288, with 135 figures.] (New York : Reinhold Publishing Corp. ; London : Chapman & Hall, Ltd., 1949. 44s. net.)

WHILE several excellent books on hardness have been published there is room for a volume devoted specifically to hardness testing, and particularly to indentation testing. The indentation test, in one form or another, is almost the only type of test used today in the evaluation of hardness in production engineering, and the summary of testing methods and their applica-

tion which the present book contains should make it attractive to anyone who is concerned with this property of materials.

Separate chapters describe the established indentation tests and their applications, and the descriptions are accurate but at times perhaps a little too concise. Bearing in mind that the book is of American origin, one may expect to find a bias in favour of the Rockwell test, but the amount of space devoted to this test is excessive. Even in the country of its origin the Rockwell test is less favoured than in the past, and the book would have been better balanced if this test had received less and the Vickers test more prominence. In any case it is difficult to justify the inclusion of a separate chapter on the superficial Rockwell test. In other respects the book is excellent. Almost all aspects of indentation testing are touched on and the fundamentals of the indentation test are clearly and concisely discussed. The inclusion of a chapter on Meyer analysis is commendable ; this application of the Brinell test deserves to be more widely known, and it is rather a pity that the author did not consider the applied ball test a stage further and include some reference to the even lesser known, but nevertheless useful, method of analysis devised by Hargreaves.

Micro hardness testing, which is rapidly becoming of increasing importance, has not been overlooked and the technicalities of hot hardness testing are briefly reviewed. The book concludes with a voluminous appendix containing much useful data on hardness numbers, conversion factors, test specifications, and hardness values. The reviewer can confidently recommend it to anyone seeking information on present-day methods of indentation testing.

J. W. CUTHBERTSON.

Photoelasticity. By H. T. JESSOP, M.Sc., F.Inst.P., and F. C. HARRIS, M.Sc., Ph.D. [Pp. viii + 184, with 164 figures.] (London : Cleaver-Hume Press, Ltd., 1949. 28s. net.)

THE two standard works on Photoelasticity available to British students are the well-known treatise by Coker and Filon and the later one by Frocht A small book by Filon for engineering students, which was published a few years before the war, served as an introduction to the theory of the subject, but there has not hitherto been a suitable textbook giving a general survey of the subject for those wishing to undertake practical work in stress exploration by photoelastic methods. The authors' aim has been to provide such a book and they have very successfully accomplished their task. While they disclaim any intention to give a complete theoretical treatment, they have included sufficient theory to enable the reader to understand the reasons underlying experimental technique and the methods which are used for interpreting the results thus obtained.

The first few chapters deal with stresses, strain and stress-strain relations, optics, polarisation, and the theory of photoelasticity, and are followed by one on the reduction and interpretation of observations, which includes descriptions of the various methods used to determine separate stresses. Following this is a short chapter on three-dimensional stresses, which will be especially welcome as it includes a description of the " frozen stress " method which has done so much to renew interest in photoelasticity in recent years. Descriptions of the photoelastic bench, straining frames, photoelastic materials and general experimental technique occupy two chapters which will specially

appeal to the student wishing to experiment for himself. The book concludes with a detailed description of five examples, fully worked out, to illustrate the methods described in earlier chapters. The examples selected are a circular disc under diametral thrust ; a rectangular block with a square hole under vertical thrust ; a simply supported rectangular beam carrying a central load ; a shaped bar with a central circular hole under tension ; and a railway-wagon coupling hook. It is unfortunate that difficulties over the supply of type have forced the authors to adopt unusual mathematical symbols, but the reader will soon accustom himself to these, and a slight irritation is quickly dispersed by realisation of the excellent quality of the contents of the book

<div align="right">A. J. S. P.</div>

Engineering Structures. Vol. 2 of Colston Papers, published as a supplement to *Research*. [Pp. viii + 260, with numerous figures.] (London : Butterworth's Scientific Publications, 1949. 25s. net.)

THIS volume presents the contributions to the Symposium on Engineering Structures held in September 1949 in the University of Bristol under the auspices of the Colston Research Society. It opens with the record of a lecture on current trends in structural research, in which Sir Richard Southwell discusses extensions of Rayleigh's principle, the advantages of potential energy over strain energy methods, systematic partition for complex structures, plastic straining and other topics.

One of the aims of the Symposium was to focus attention on non-linear behaviour, and so a number of the contributions are devoted to plasticity in structures and to instability. In a comprehensive paper, Roderick and Phillipps discuss the carrying capacity of mild steel beams and Horne considers the effect of variable repeated loads in the plastic range. A mathematical analysis of the plastic deformation of rectangular plates under uniform edge loads is presented by Hopkins, using the von Kármán approach. In the field of instability, Pugsley discusses the strut in a non-linear medium and applies this theory to the waving in a tension field web. Hoff presents a paper on dynamic criteria of buckling and Winter considers the performance of compression plates.

Other papers are devoted to structures of thin steel plates. Sparkes, Chapman and Pippard describe experiments on the flexure of rectangular box girders, and the analysis and performance of light members produced by the cold forming of sheet steel are discussed by Winter, Lansing and McCalley.

The remaining contributions deal with a variety of topics. The shortening effect in pure torsion is discussed by Cullimore, Cox considers the effective stiffness of stringers and Francis describes investigations on aluminium alloy joints. Vogt presents a paper on the deformation of concrete under sustained load, and the design of structures on the basis of assumed deformation is discussed by van der Neut. Finally, an interesting review of the testing of structures is given by Owen.

This volume gives an account of recent researches on a variety of structural problems and it will provide the research worker with much authoritative material. It merits a distinguished place in structural literature.

<div align="right">A. D. R.</div>

Heat Pumps and Thermal Compressors. By S. J. DAVIES, D.Sc. (Eng.), Ph.D., M.I.Mech.E. [Pp. 126, with 39 figures.] (London : Constable & Co., Ltd., 1950. 9s. net.)

THE past twenty years have seen a number of developments in the application of thermodynamics to engineering, the most notable being that of the gas turbine. Another field in which considerable progress has taken place, even if less spectacular, is that of heat pumps, and Prof. Davies has given an excellent survey of these devices in the book under review. Actually it is the only work on this subject published in Great Britain, and is based on a set of public lectures given by him at King's College, London.

The first of these treats of the basic and actual cycles of such pumps. So far few of these plants exist in this country, due no doubt to our equable climate, but there are several in the U.S.A. The largest installation here is that at Norwich. This is described in detail in Lecture II. As a result of fuel shortage in Switzerland, several small plants have been developed there and the experience gained is sufficient to show that these pumps are worthy of consideration here as a means of heating buildings, combined with economy of fuel. Examples are also given in connection with industrial plants.

In Lecture III a detailed analysis is given of a dual purpose plant which may be used either for heating or cooling buildings, combined with air conditioning. The modification of the circuit necessary to effect this change-over is made by operating suitable valves.

The final lecture, IV, compares space heating by simple boilers with that by heat pumps driven by electric motors or oil engines.

Various thermal compressors are also described, together with the Philips hot-air engine, a war-time rejuvenation of the Stirling engine of 1827.

Within the size of the book it would be difficult to imagine a more lucid description or a more thorough analysis of the subject. The volume is a credit to the author and well worth studying.

B. LLOYD-EVANS.

CHEMISTRY

Annual Reports on the Progress of Chemistry for 1948. Vol. 45. [Pp. 379.] (London : The Chemical Society, 1949. 25s. net.)

THE latest number of the *Annual Reports of the Chemical Society* conforms to the usual pattern of these volumes and comprises a survey of aspects of the most important branches of pure chemistry and related subjects up to the end of 1948. The part on general and physical chemistry contains sections on chemical reactions induced by ionising radiations, the structure of aqueous solutions of soap-like substances, chemical kinetics and homogeneous thermal gas reactions. The article on inorganic chemistry is general and covers the whole field, and the organic section contains reviews on general methods, homolytic reactions, terpenes, colchicine and related compounds, recent work on the reactions of organic sulphur compounds, and heterocyclic compounds. Biochemistry is represented by the function of small molecules in biosynthesis, partition chromatography, the chemistry of insulin and the chemotherapeutic approaches to the T.B. problem, and the final section devoted to analytical chemistry discusses analytical emission spectrography, flame photometry, volumetric analysis and the analysis of sea water.

Those articles, written by experts in their particular fields, fully maintain the high standard established in previous years. It is noticeable that there has been a distinct trend in recent numbers and again in this volume on the part of many of the authors towards providing complete surveys of various aspects of chemistry rather than presenting a true annual report of the whole field of chemistry for the year under review, as in the earlier volumes. With the advent of *Quarterly Reviews*, future numbers of the *Annual Reports* may be expected to revert gradually to the original form.

The series well deserves the high esteem in which it is held both at home and overseas.

A. W. JOHNSON.

How Chemistry Works. By ARTHUR J. BIRCH, M.Sc., D.Phil. [Pp. 218, with 4 plates and 36 figures.] (London : Sigma Books, Ltd., 1949. 8s. 6d. net.)

THIS is one of the Sigma Introduction to Science Series, and it is said to be intended chiefly for the layman ; but in the reviewer's judgment it is in many places above the average layman's head. It is extremely difficult to present chemistry to the layman, especially if it is to be done concisely, and this book mentions a great many topics in very few pages. In it are discussed the history of chemistry, the atomic theory, the classification of the elements, catalysis, chemical techniques (crystallisation, distillation, chromatography, analysis, and so on), nomenclature (with a brief reference to the Dyson system), the development of the knowledge of the structure of molecules (including optical isomerism), the methods of synthetic organic chemistry, some aspects of industrial chemistry (including plastics), the different outlook of the research worker in pure and applied chemistry, photosynthesis, enzymes, vitamins, hormones, the origin of life, the labelled carbon atom technique, poison gases, the place of chemists in the community, and many other aspects of chemistry and its related sciences. It is obvious that these topics can only be most briefly treated in 218 pages, and that they have been chosen for their topical interest, and not because they are easy to explain and understand. The author has been careless in introducing topics such as formulæ before explaining them, though there is a two-page note at the end on this subject. In the book's favour it can be said that it is well written, accurate, up-to-date, and interesting. It is more likely to be of interest to the boy in his teens with a good background of elementary chemistry than to the layman with little or no chemical knowledge.

L. M. MIALL.

Fundamentals of Qualitative Chemical Analysis. By ROY K. McALPINE, Ph.D., and BYRON A. SOULE, Sc.D. Third edition. [Pp. xii + 370, with 3 figures.] (New York : D. Van Nostrand Co., Inc. ; London : Macmillan & Co., Ltd., 1949. $3.50 or 26s. net.)

THE authors of this book hold the view that the main purpose of a course in Qualitative Analysis is to widen the student's knowledge of inorganic chemistry and to impress upon him the cardinal importance of working under controlled conditions if reactions are to be carried out successfully. They believe, too, that the laboratory period in the student's time-table is essentially a time for the practical study of reactions rather than for the testing of analytical ability. Accordingly, they make a much greater and more prolonged

use of solutions of known composition than we do in this country, and this book is evidently the training manual they use for their teaching at Ann Arbor in the University of Michigan.

The laboratory exercises based on the examination of solutions of known composition, the numerous problems on theory and practice to be found at the end of many chapters and in the appendix, the chapter on study aids where questions of fifteen types are fully illustrated and discussed, and the treatment of the theory underlying chemical analysis offer a thorough grounding and training for the analyst-to-be. The beginner in this country is trained on different lines and, by comparison, is pitchforked into the task of coping with the practical issue of identifying the constituents of a mixture of unknown composition.

Readers accustomed to the conventional type of textbook on qualitative analysis will find novelty in the way in which the subject matter of this book is presented. For example, in Chap. IV the application of the ionic theory to group separations is dealt with mainly by working out and explaining a series of problems relating to the precipitation of five of the six groups into which the twenty-three cations discussed are divided. In the chapters on each analytical group the common compounds and reactions of the ions are described and this is followed by practical instructions, with explanations, for precipitating and separating the constituents of the group ; then come a list of equations representing the reactions involved, a summary and review to provide an exercise in revision, and, finally, a series of laboratory exercises with solutions of known composition. These chapters are sound and are full of useful instruction and information ; in addition, they contain sections dealing with the group concerned in relation to the groups that precede and follow it—a valuable feature for the beginner, who seldom has a true appreciation of this interrelationship.

The book contains a wealth of analytical knowledge derived from ripe experience of the subject and, if he studies this work, the teacher of qualitative analysis will find plenty to interest him. Whether he will adopt it for his students will depend on his view as to the way in which the subject should be taught.

L. S. THEOBALD.

Advanced Chemical Calculations. By SYLVANUS J. SMITH, M.A. [Pp. viii + 454, with 38 figures.] (London : Macmillan & Co. Ltd., 1950. 17s. net.)

As pointed out by the author in the preface to this book, the term " advanced " is largely relative. No student need be overawed by its inclusion in the title of the present volume, which is intended to be a continuation of the same author's *Introductory Chemical Calculations*. It includes a very good series of worked and unworked problems ranging from below Intermediate or Higher School Certificate level to rather beyond the present General degree standard. Many of the examples are taken from papers set at public examinations. To cover such a wide range in one small volume is difficult, and it is only natural that the theoretical basis is only briefly mentioned. It is probably with the aim of appealing to relatively junior students that the approach is classical, and that more recent topics are either omitted or receive only brief mention.

The book is of a type which should be very useful indeed for the student of about Intermediate standard and also in relation to certain of the aspects

of the subject studied by the degree student. In preparing a second edition the author might consider the advisability of introducing a few other and more advanced exercises which would make it still more valuable to Special Degree students in Chemistry and students of Chemical Engineering. Such additions might well include a few calculations based upon actual measurements recorded in the literature, for which references could be quoted. Students could then compare their interpretation of the results with that of the original author.

<div align="right">J. W. S.</div>

Chemical Laboratory Experiments. By GEORGE W. WATT and LEWIS F. HATCH. [Pp. x + 185, with 35 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 17s. net.)

AMERICAN elementary textbooks usually differ considerably in outlook from their British counterparts, and this book is no exception. Most of the material presented is at a post-Matriculation level, but, as the syllabus for Intermediate is not covered, the book cannot be recommended for general use in this country.

The main criticism to be levelled against it is that basic, " bread-and-butter," chemistry is largely avoided. Qualitative inorganic analysis (for six cations and three anions) is dismissed in three pages. A number of useful and instructive organic preparations is given, including the preparation of " Thiokol," phenolphthalein, and D.D.T., but no place is found for such substances as ether, acetamide, nitrobenzene, etc. Quantitative technique is left at a primitive stage, e.g. the most accurate balance to be used weighs to 0·01 g. Volumetric analysis is limited to acid-alkali titrations and no mention is made of normalities.

Some of the experiments are of Matriculation standard only and the choice and order seem puzzling : thus, after useful chapters on colloids and electrochemistry, the reader is confronted with a section on the determination of the density of metals. At the end of each experiment there is a report and questionnaire to be filled in by the student, and the whole book savours of an efficiently organised, but rather impersonal, course.

On the other hand, the experiments and demonstrations described seem good, and, after a perusal of the book, one feels compelled to try some of them out. There is plenty of material to keep up the interest of the student and a laudable attempt is made to relate " practical " chemistry to the application of chemistry in daily life.

In short, here is a book which is unsuitable for use as a class-book, but which contains much interesting and refreshing material. It might well be read by teachers of chemistry, so that they could select from its contents some new and instructive experiments to incorporate into their courses.

<div align="right">J. F. H.</div>

Colloid Science. Edited by H. R. KRUYT. Vol. II : **Reversible Systems.** [Pp. xx + 753, with 473 figures.] (Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. 90s. net.)

AN accumulation of new factual material and the steady development of methods of experimental and theoretical attack in recent years have emphasised the need for a comprehensive treatment of colloidal systems that should

be in step with contemporary knowledge. The recent publication of Alexander and Johnson's *Colloid Science* went far to meet this need for English readers. It seems likely also to be met in a rather different way by a work bearing the same title, of which the book under review is the second volume, the first being still in preparation. This volume deals with systems in thermodynamic equilibrium, and their colloid components. It has been produced by a small team, each member of which has made important contributions to the subject on which he writes. A preliminary survey by H. G. Bungenberg de Jong, followed by chapters on the formation and structure of macromolecules (R. Houwink), thermodynamics of long-chain molecules (J. J. Hermans), and physical properties of randomly coiled chain molecules (J. J. H.), and an explanatory review of methods of determining molecular weight (J. J. and P. H. Hermans) provides an admirable introduction to the systematic discussion of non-electrolytic (R. H.) and electrolytic (J. T. G. Overbeek and H. G. B. de J.) macromolecular sols ; crystallisation, coacervation, flocculation, properties of ionised groups, complex colloid systems, and morphology of coacervates (H. G. B. de J.) ; gels (P. H. H.) ; solid macromolecular systems of one component (R. H.) ; and micellar colloids (H. L. Booij).

This is not a collection of independent monographs. The different divisions of the subject are treated so as to show the essential continuity between macromolecular and micromolecular systems, and the value and fertility both of a classical method of approach and of modern concepts such as that of the randomly coiled chain molecule. The material has been carefully selected, topics omitted or only briefly referred to being those on which information is readily accessible elsewhere. Practical methods of investigation are not described. There is no systematic treatment of special groups of colloid materials, though many of these are fully discussed in various chapters dealing with the properties of systems in which they occur. The sections on coacervation, complex systems, and the morphology of coacervates (the last-named being of a more descriptive character than the rest) are especially welcome in view of the relative inaccessibility of many of the original papers.

The book is well produced and the diagrams are excellent. There are cross-references in the text and a full name index and subject index. References to published work are brought up to 1948. The translation is clear and readable, and occasional lapses from current English usage do not obscure the meaning. This book is a valuable accession to colloid literature and is strongly commended to those who need an up-to-date fundamental treatment of the subject.

F. L. USHER.

Thermodynamics of Dilute Aqueous Solutions : with Applications to Electrochemistry and Corrosion. By M. J. N. POURBAIX. Translated by J. N. AGAR, M.A., Ph.D. With a Foreword by U. R. EVANS, M.A., Sc.D., F.R.S. [Pp. xvi + 136, with 27 figures.] (London : Edward Arnold & Co., 1949. 30*s*. net.)

THE English version of Dr. Pourbaix's *Thermodynamique des Solutions Aqueuses Diluées* is based on the second impression of the book, published in 1946. . Dr. Pourbaix's fascinating and valuable discussion of the subject is presented by Dr. Agar in a translation that reads like an original work.

The author discusses the general relationships between the experimental results and the theoretical deductions of many workers, including substantial contributions from his own work. Apart from its general electrochemical interest, there is no doubt that the book will prove most illuminating and extremely valuable to those interested in "corrosion reactions." As Dr. Evans points out in his Foreword, the conception of domains of "corrosion," "passivité" (translated as "immunity") and "passivation" is vividly illustrated on the appropriate diagrams of equilibrium potential against pH. To quote Dr. Evans, "Dr. Pourbaix's treatment . . . offers a common elucidation of numerous problems which are to-day regarded as quite distinct, and concentrates a vast mass of pertinent data in diagrams which, to those who have gained familiarity with this system, are remarkably simple."

A notable feature of the treatment is the author's generous acknowledgment to earlier and to contemporary workers and his clear statement of the assumptions on which his deductions are based. He also draws attention to the doubts concerning the accuracy of much of the experimental data on chemical potentials and he suggests lines of research likely to be most fruitful in the future.

The subject matter includes a detailed discussion of the following systems : Cu-H_2O, Fe-H_2O, Cr-H_2O, N-H_2O. A list of 137 references and an index are provided.

The general production of the book is of a high standard worthy of the subject and of the admirable way in which the matter is presented by the author and the translator. A few printing errors have been noticed, but these are minor blemishes. The relatively high price of the book in relation to its size is presumably justified by the additional costs of translation.

F. WORMWELL.

Industrial Rheology and Rheological Structures. By HENRY GREEN. [Pp. xii + 311, with 78 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 58s. net)

A PUBLISHERS' note acknowledges the assistance of Miss Ruth N. Weltmann, who worked with the late Henry Green for several years, in seeing this book through the press after the untimely death of the author. Henry Green will be remembered by older rheologists chiefly for his early association with Bingham in the use of a capillary plastometer and his application of the microscope to the study of plastic flow ; more recently (1942) he developed a rotational viscometer, here fully described, which embodied many improvements. He explains his preference for the latter type (1) by showing that data obtained for two paints by the capillary tube method agree neither with the Bingham nor with the fuller Buckingham equation and (2) by quoting Reiner and Riwlin's proof that a rotating-cylinder method should allow plastic viscosities and yield-points to be determined for "Bingham bodies." He gives no hint, however, why slippage should occur only in a capillary and not at a moving surface, nor does he attempt to indicate how to discover what parts of a consistency curve are of most practical importance. Pseudo-plastics are somewhat cursorily treated, but an illuminating section deals with thixotropy and the examination of its breakdown. His rheological system is mainly a condemnation of the so-called one-point method for finding apparent viscosity, but he also stresses the value of the microscope in the study of types of flow, particle sizes and flocculation. Many of his hints

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on microscopy and on the preparation of mounts will be found valuable (though his microphotographs are reproduced without a scale). The chapter on the electron microscope might well have been reduced to a literature reference.

Errors or misprints have been noticed on pp. 11, 13, 17, 119, 258, 262 and 294.

Most rheologists will be glad to read this book, but few will buy it for their private shelves.

GUY BARR.

Experimental Physical Chemistry. By FARRINGTON DANIELS, JOSEPH HOWARD MATHEWS, JOHN WARREN WILLIAMS, PAUL BENDER, GEORGE W. MURPHY and ROBERT A. ALBERTY. Fourth edition. International Chemical Series. [Pp. xiv + 568, with 165 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 38s. 6d. net.)

A SOUND practical course is essential to the study of physical chemistry, but the failure of many textbooks of the subject is that they are more collections of instruction sheets for the performance of a series of classical measurements and afford little link with the theoretical aspects of the subject. No such complaint can be made with regard to this book, the first section of which gives details of 64 experiments suitable for performance by students. The treatment in each case includes a preliminary discussion of the theory underlying the experiment, followed by a description of the method and an indication of the means of calculating the results. Whenever possible, notes are added regarding the practical applications of the technique involved, and suggestions made for developments of a more advanced character. The experiments described range from vapour density measurements by the Victor Meyer method to the study of Raman spectra, and the apparatus used from the Ostwald viscometer to the Geiger counter.

The second section of the book, comprising the last 200 pages, is devoted to a description of apparatus and methods not included in the set experiments. A particularly useful feature is a discussion of various types of valve circuits and of the components used in them.

The book is based upon the courses held at the University of Wisconsin, and hence it is only natural that many university teachers responsible for practical courses may disagree with the relative emphasis laid upon the different branches of the subject, or may find their pet experiments omitted. There can be few, however, who will not be able to gain some new ideas from the suggestions put forward. Altogether it is a book to be cordially recommended, particularly to teachers of the subject who believe that certain branches of physical chemistry belong rather to the laboratory than to the lecture theatre.

J. W. S.

Synthetic Methods of Organic Chemistry. A Thesaurus. Vol. II, 1945–46. By W. THEILHEIMER. Translated from the German by A. INGBERMAN. [Pp. xii + 324.] (New York and London : Interscience Publishers, Inc., 1949. 60s. net.)

THE second volume of Theilheimer's *Synthetic Methods* covers much of the literature of organic chemistry of 1945–46 but, as many American chemical

journals were not available to the authors at the time of publication, the abstracts are largely derived from the English, French and Swiss literature. The author proposes to include the American publications in a later volume. The system employed by Theilheimer has been outlined in the review of his earlier volume (SCIENCE PROGRESS, 1949, **37**, 157) and, although this classification has not been widely employed by organic chemists, it does have the advantage of minimising the necessity of including the same reaction under several different headings. For those who do not care to use this system there is a good index which covers Vol. I as well as the present volume, and there should be no difficulty in locating any particular reaction. It is not possible in books of this size to give a comprehensive cover of the literature and the Theilheimer volumes are intended to be only preliminaries to any complete literature survey, although on the other hand they do enable the chemist to assess rapidly an organic reaction without recourse to an extended search through original papers.

The English translation has lost little of the accuracy of the German text and in this respect is an improvement on the translation of Vol. I. The very severe price will undoubtedly be a handicap to individual purchasers for many of whom a volume in this price range must be regarded as a rare luxury. Readers who are accumulating this series in the English translation should note that Vols. III and IV will be published in the German edition only, although it is hoped to resume the translation with Vol. V.

<div align="right">A. W. JOHNSON.</div>

Advanced Organic Chemistry. By G. W. WHELAND. Second edition. [Pp. xii + 799, with 31 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 64*s.* net.)

ONE of the most welcome aspects of the present-day teaching of organic chemistry is the increasing tendency towards a systematic treatment rather than a presentation of a mass of unconnected facts. It is of course still necessary to teach the reactions and methods of preparation of alcohols, ketones, amides and so forth, but a full appreciation of why the compounds react the way they do can only come from a knowledge of the fundamental theory of organic chemistry. This trend is reflected in the increasing number of books dealing with this aspect of the subject which have appeared in recent years and among them Wheland's present volume undoubtedly takes a high place. The book is designed for a second course in organic chemistry for students who already have a knowledge of elementary organic and physical chemistry. The factual matter is presented logically throughout and the author has made a good overall selection of material. Major topics include types of organic structures ; structural isomerism and stereoisomerism ; stereochemical steric effects ; resonance ; molecular rearrangement ; tautomerism and free radicals. A mild criticism of this choice would be the omission of a discussion on aromatic substitution, but on the other hand the extensive treatment of molecular rearrangements will be invaluable. The binding and general format of the book conform to the high standard which one requires in a book of this price. Prof. Wheland has made a valuable contribution to the literature of organic chemistry, and his book will undoubtedly have a wide appeal.

<div align="right">A. W. JOHNSON.</div>

Organic Chemistry. By G. BRYANT BACHMAN. International Chemical Series. [Pp. x + 432, with 29 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 36*s.* 6*d.* net.)

THE author refers readers to 17 recent works on organic chemistry, and one might well ask if there remains unmet any demand for another text on this subject. This book, which is intended for a year's course, but contains much more than any newcomer could assimilate in that time, provides the answer.

In outline it follows the familiar sequence of aliphatic, aromatic, and, in reasonable detail, heterocyclic compounds. The author has successfully avoided the uninteresting compilative presentation which is often encountered. Theoretical foundations, electronic aspects, nomenclature, relations between constitution and colour or physiological action, technical topics, biochemical and pharmaceutical advances, all these and many others are surprisingly fully represented and appropriately introduced with close understanding of the student's difficulties. Formulæ are of good size and clarity and remain of high quality in such difficult fields as those of the carbohydrates and polycyclic compounds. The flow-sheets and tables, *e.g.* of fruit essences, enzymes, fats, steroids, medicinal phenylethylamines, etc., serve a more useful purpose than the usual tables of homologues. Only the pictorial illustrations mar the whole work ; chemical principles are hardly emphasised by pictures of a " Tiny Tim " rocket being launched or striking its target, or of body organs associated with the assimilation of food. Probably the inclusion of representative literature references would have been better than saying that a competent librarian could supply them, and would have been preferable to the exercises in each chapter. Very little of the presentation will seem unfamiliar to the reader outside U.S.A., apart from the occasional use of such terms as " ethanoic acid " and " isologs." On the other hand, the book contains a wealth of up-to-date detail which might be sought in vain in many longer works ; the structures of the penicillins, of Paludrine, Pyribenzamine, Demerol, Hetrazan, etc., are examples.

This book will be valuable not only to the student making chemistry his profession but also, as the author intends, to the increasing number who must read organic chemistry as part of the background of other studies ; to these indeed it can be more than a textbook, it can be a dependable reference work for a considerable time to come. A. H. COOK.

Organic Reactions. Vol. V. ROGER ADAMS, Editor-in-Chief. [Pp. viii + 446.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 48*s.* net.)

" GOOD wine needs no bush " and this latest volume of a series which has become essential for every library and all but essential for every serious research worker in organic chemistry needs no recommendation from a reviewer. To the thirty-eight reactions treated in the four earlier volumes this volume adds ten more, *viz.* " The synthesis of acetylenes," by T. L. Jacobs (78 pp. ; 519 refs.), " Cyano-ethylation " by H. A. Bruson (57 pp. ; 128 refs.), " The Diels-Alder reaction : quinones and other cyclenones " (the third article on the diene synthesis) by L. W. Butz and A. W. Rytina (57 pp. ; 133 refs.), " Preparation of aromatic fluorine compounds from diazonium fluoborates : the Schiemann reaction " by A. Roe (36 pp. ; 142 refs.), " The Friedel-Crafts reaction with aliphatic dibasic acid anhydrides " by E. Berliner (61 pp. ; 296 refs.), " The Gattermann-Koch reaction " by N. N.

Crounse (11 pp. ; 35 refs.), " The Leuckart reaction " by M. L. Moore (30 pp. ; 57 refs.), " Selenium dioxide oxidation " by N. Rabjohn (56 pp. ; 324 refs.), " The Hoesch synthesis " by P. E. Spoerri and A. S. Du Bois (26 pp. ; 110 refs.), and " The Darzens glycidic ester condensation " by M. S. Newman and B. J. Magerlein (28 pp. ; 87 refs.), all of which are of the usual high standard.

Surveying the forty-eight topics dealt with in the first five volumes of this series there appears to be some tendency to choose for review relatively minor reactions of recent development rather than the older " bread-and-butter " reactions ; thus, to take four examples at random, there have been no articles on hydrogenation, ozonolysis, esterification or aromatic nitration. It would add even more to the value of the series if one such article, which would necessarily be a long one, could be given in each subsequent volume in place of three or four of the shorter articles.

As usual, the volume is well produced in a manner which befits a work which has established itself as a permanent and valuable feature of the literature of organic chemistry. H. N. RYDON.

Electronic Interpretations of Organic Chemistry. By A. EDWARD REMICK, Ph.D. Second edition. [Pp. viii + 600, with 31 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 48s. net.)

WHEN the first edition of Dr. Remick's textbook appeared in 1943, it at once achieved a leading position in the exposition of the principles of organic chemistry, as they have been developed, on the basis of the electronic theory of structure, and with the aid of other physicochemical concepts, largely during the last twenty-five years. The new " Remick " again takes a leading place in the more copious literature of today. A considerable section of the text is rewritten or reshaped, and part of it is entirely new. One result is that the new book is better balanced, better knit together, and more satisfying in its logical development as an exposition of the theoretical structure of organic chemistry, than was the old. The new book also contains a much better selection of illustrations, drawn from the observations of organic chemistry, and showing the significance and utility of the theoretical ideas. Special mention should be made of the new chapter on stereochemical factors, and of the useful companion chapters dealing with electron-sharing and electron-pairing reactions (i.e heterolytic and homolytic reactions). ·

A review is expected to be critical, but the present reviewer can find little to criticise. Possibly he has somewhat less faith than the author in the validity and significance of available bond-energy values. He might also hesitate to epitomise the " basic principles " quite so tersely, though the pedagogic value of the author's method is admitted. But these are mere matters of judgment or taste. The book is sound, well-composed and highly educative. Undoubtedly it constitutes the best available basis of instruction in book form in the subject to which it is devoted. C. K. I.

An Elementary Text-book of Organic Chemistry. By D. D. KARVÉ, M.Sc., A.I.I.Sc., Ph.D. Sixth edition. [Pp. viii + 192, with frontispiece and 29 figures.] (Poona : Dastane Bros. Home Service, Ltd., 1949. Rs.2.12.)

THIS introduction to organic chemistry by the Professor of Chemistry at Fergusson College, Poona, is written to meet the requirements of the syllabus,

which is appended, in organic chemistry for the Intermediate Science Examination of the University of Bombay, by which University this book is recommended. Two-thirds of the book is devoted to a survey of aliphatic chemistry, after which follows a brief account of aromatic compounds, a tabular summary of the methods of preparation and properties of important compounds, and appendices containing some qualitative analysis, examination questions and numerical problems, and syllabuses in organic chemistry for the first examinations of several Indian Universities.

The six editions of this book in twelve years clearly indicate that it admirably fulfils its immediate purpose of covering an examination syllabus. However, as an introduction to present-day organic chemistry it is less satisfactory. Without intending disrespect to our chemical forebears this book makes a nineteenth-century approach to the subject. Electrovalency and covalency are not distinguished (e.g. pentacovalent nitrogen, pp. 26, 156) and there is no discussion of the atomic structure of carbon in relation to its ability to form organic compounds. Although optical isomerism is described and illustrated for the lactic and tartaric acids, the idea of geometrical isomerism is not introduced. As is perhaps inevitable in an elementary text, many of the generalised methods are only half truths (e.g. the hydrolysis of 1 : 1 : 1-trichloroalkanes as a method of preparing carboxylic acids, p. 87) and lack an adequate indication of experimental conditions (e.g. the hydrolysis of esters, p. 87). The section on aromatic compounds is marred by the perpetuation of the error that in the nitration of benzene sulphuric acid is added to absorb the water and so prevent dilution of the nitric acid. T condenser in the diagram on p. 70 is upside down, while the phrases " fumi cupboard " and " catalyser " are unexpected. However, the main pu of this introductory text is well served and at its modest price (4s.) s continue to interest Indian students in organic chemistry.

S. H. H

Selected Topics from Organic Chemistry. By D. D. KARVÉ, A.I.I.Sc., Ph.D., and G. D. ADVANI, B.A., M.Sc., A.I.I.Sc. edition. [Pp. vi + 418.] (Poona : Dastane Bros. Home Ltd. Rs.10.–.)

THIS more advanced text by Prof Karvé and Prof. Advani consists of thirty chapters on various aspects of organic chemistry. Thirteen chapters are devoted to natural products, whilst the remainder are divided between theoretical topics, surveys of reactions and reagents, and the book is concluded by specimen examination questions and answers. The advent of a second edition within two years indicates that this book is proving popular with Indian students and it might also be suitable for Pass Degree students in this country.

The chapters on natural products are the most satisfying, although little of the work of the past decade is included, while the accounts of the determination of structures or of syntheses lose in interest through the absence, in all but a few cases, of names and dates. The chapters on theoretical topics are much less satisfactory. Although electrovalency and covalency are distinguished and the idea of resonance introduced, little use is made of these concepts. There is no account of the mechanism of aliphatic substitution reactions and of the influence of structure on reactivity. In discussing aromatic substitution little of the work of the past thirty years is mentioned

and the present-day theory is discarded for a mechanism involving the addition of the entire reagent molecule at the ends of a conjugated system. The chapter on compounds of abnormal valency, *i.e.* free radicals, suffers from the lack of a clear definition of a free radical and of distinguishing between heterolytic and homolytic fission of a bond. For these reasons too the chapters on tautomerism, oxidation, and reduction are inadequate.

If the level of the chapters on theoretical and general organic chemistry were raised, this book would place before the degree student a concise survey of the subject at a reasonable price (15*s*.). S. H. HARPER.

An Introduction to Practical Organic Chemistry. By R. V. V.
NICHOLLS. Second edition. [Pp. x + 226, with 21 figures.] (Toronto and London : Sir Isaac Pitman & Sons, Ltd., 1949. 15*s* net.)

THIS excellent little book is divided into two sections. The first (pp. 1–56) is a sound and well-balanced account of organic laboratory technique, clearly written by an experienced laboratory worker familiar with, but not hypnotised by, modern methods. It forms a sound introduction to the section on "Synthetic and Analytical Procedures." This second section differs markedly from most practical textbooks in use in this country and the reviewer feels that it might well serve as a model for a much-needed overhaul of our present rather stereotyped system of "preps." and "spots." The practical work is organised into thirty-one "assignments," each designed to occupy a three-hour laboratory period, although some seem rather too long for this. A typical assignment comprises a brief theoretical introduction, a preparation on a moderate scale, and a number of test-tube experiments designed to illustrate the general topic ; review questions serve to connect each assignment even more closely with its theoretical background. It is pleasing to find the measurement of physical properties and a simple piece of kinetic work included. The approach is heuristic, the student being encouraged to think for himself and to draw his own conclusions from his experiments. The experimental directions are clear, concise and sensible and, on the whole, the topics covered are well chosen. A student working through this course will have received a thorough grounding in practical organic chemistry and, what is perhaps even more important at this stage, will himself have verified experimentally a large proportion of the statements made in an elementary lecture course.

The book is well printed and stoutly bound, and the figures are clear and well drawn ; misprints are few and only one (on p. 176) is serious and not obvious. It is a pity that the author's evident enthusiasm for systematic nomenclature has led him into such pedantries as calling acetic acid ethanoic acid, and ether ethoxyethane. This is a minor criticism and is made only because such blemishes are less tolerable in a good book, as this is, than they would be in a mediocre one. H. N. RYDON.

Practical Organic Chemistry. By J. J. SUDBOROUGH, Ph.D., D.Sc.,
F.R.I.C., and T. CAMPBELL JAMES, M.A., D.Sc., F.R.I.C. Second edition. [Pp. xvi + 450, with 99 figures, including 1 plate.] (London and Glasgow : Blackie & Son, Ltd., 1949. 15*s*. net.)

THIS book follows the style of the previous edition and the authors state that "an endeavour has been made to incorporate modern methods of

quantitative analysis, new synthetic methods . . . " As a text which presents clear instructions on carrying out numerous simple preparations and other exercises in organic chemistry it is mostly satisfactory. It must be said, however, that the descriptions sometimes appear inadequate even for the elementary student ; thus the description of the rather remarkable apparatus (p. 306) for catalytic reduction might well have mentioned that caution is required at least in finally opening the apparatus, and the preparation of the catalyst might usefully have been included.

It is stated that the book has been " completely revised . . .," but the illustrations remain archaic. While all-glass apparatus is mentioned without being otherwise evident, surely one should not lead students to believe that tap-funnels (Fig. 1), fraction-collecting devices (Figs. 6–9), filter flasks (Fig. 16), reflux condensers (Fig. 18), etc., are today much in use as depicted ; surely the student should not remain completely ignorant of modern fractionating columns, many micro determinations, electrical heating mantles and similar items ; the statement that " with a modern rotary pump pressures of 0·1 mm. are reached " (p. 8) is hardly sufficient. Again, as another example, it seems curious, bearing in mind the advances in preparative methods over the last decade, that revision has added to the many old references only five later than 1939. In short, while this text is as good as ever it was, many will look in vain for what might reasonably have been included ; they will regret not what the book contains but what is omitted.   A. H. COOK.

Quantitative Organic Analysis via Functional Groups. By S. SIGGIA, Ph.D. [Pp. viii + 152, with 27 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949.   24s. net.)

THIS book is a compilation of standard methods for the determination of the purity of simple organic substances, and lists a number of tested procedures, both new and old. It deals in the main with those organic analyses which can be achieved successfully by means of standard volumetric procedures, such as acid—alkali or iodine—thiosulphate titration, but includes also a few well-known gasometric methods that are to be found in every organic chemistry textbook.

Since no similar laboratory handbook has been published for many years, Dr. Siggia's compilation will be of considerable help to analysts who wish to have at hand routine procedures for applying volumetric methods to the rapid analysis of simple substances, such as carboxylic acids, alcohols, ketones, phenols, amines, acetylenes, etc , though it does not draw sufficient attention to the fact that the simple routines may need drastic modification when complex molecules or unusual mixtures have to be dealt with. The book has some surprising omissions. For instance, there is no mention of the estimation of alkyl or acyl halides by hydrolysis and subsequent reaction with silver nitrate, or of the titration of aldehydes, such as the reducing sugars, with Fehling's solution, potassium ferricyanide, or similar reagents. The numerous gasometric methods of Van Slyke for the analysis of aliphatic amines, amides, amino-acids, etc., again have not been included, together with any real indication of the many ways in which colorimetric analysis can be applied to organic chemistry. Instead, the book ends with a scrappy account of methods of separating mixtures, which might have been culled from any standard textbook of chemistry and is of no direct value as a guide to laboratory technique.

The subject of organic group analysis is an important one, and it is a pity to see that it has been handled in so perfunctory a manner. A laboratory manual that dealt adequately with it would extend to at least three times the length of Dr. Siggia's volume of 152 pages.

W. A. W.

Advances in Carbohydrate Chemistry. Vol. 4. Edited by W. W. PIGMAN, M. L. WOLFROM and S. PEAT. [Pp. x + 378, with 9 figures.] (New York : Academic Press, Inc., 1949. 58s. 6d. net.)

THE recent marked improvement in the quality and quantity of reviews covering selected topics in the rapidly-expanding field of carbohydrate chemistry is attributable in large measure to the advent of this series of *Advances in Carbohydrate Chemistry*, which furnishes both summaries of early pioneering studies and progress-reports on current investigations. The impressive list of contributors to this fourth volume itself affords an ample guarantee of the calibre of the articles presented.

Two reviews are devoted to sucrose and its derivatives. One, contributed by I. Levi and C. B. Purves, is a logical survey of the methods by which the structure and configuration of this disaccharide have been ascertained. In the other, L. F. Wiggins considers the utilisation of sucrose in the light of present world production. He foresees the use of sucrose and other constituents of the sugar cane as raw materials in the manufacture of such diverse commodities as fuels, plastics, drugs, fine chemicals and fertilisers.

No carbohydrate chemist can fail to be fired with the enthusiasm of J. K. N. Jones and F. Smith as they unravel the tangled structures of plant gums and mucilages, or to appreciate the manner in which H. G. Bray and M. Stacey have correlated the structures of blood-group polysaccharides derived from various sources, but the article by E. L. Harris on Wood Saccharification is, at times, too technical to maintain the lively interest of the reader.

Two reactions of wide application in sugar chemistry, namely the Wohl degradation of acetylated nitriles of aldonic acids and the interaction of boric acid with carbohydrates, are discussed comprehensively by V. Deulofeu and J. Böeseken, respectively. These summaries, which include details of the mechanisms and limitations of the reactions, should be useful reference works.

C. S. Hudson's re-interpretation of early investigations into the nature of apiose and the glycosides of the parsley plant offers a sound basis for future studies in this field. C. Neuberg shows how a wide variety of carbonyl-, ethylenic-, and nitro-compounds can be reduced by yeasts and bacteria at the expense of sugars. A useful list of the properties of known derivatives of the hexitols is given in an article by R. Lohmar and (the late) R. M. Goepp.

E. J. B.

The Art and Science of Brewing. By C. A. KLOSS, B.Sc., A.R.I.C. [Pp. x + 121, with 8 plates and 9 figures.] (London : Stuart & Richards, 1949. 12s. 6d. net.)

WITHIN its textual compass this small book, which joins a very small band of larger or more specialised works on brewing, covers in elementary but thoroughly enjoyable fashion a considerably wider field than its title might at first suggest. Thus, after brief historical and scientific introductions, only some 40 pages are concerned with brewery practice, the remainder being

devoted to discursive chapters on brewing research in various countries, the chemistry of the subject, some scientists, such as Pasteur and Koch, distinguished for work having particular significance for or associated with brewing, and other subjects.

The author has compressed with notable skill and consideration a great deal of information into these pages. Brewing materials, brewing plant and practice, coopering, Continental systems of malting and brewing generally, chemistry, biochemistry, bacteriology, mycology, all these and many other topics are here blended with sufficient detail to make the whole interesting to the brewer, scientist and layman alike. The plates, which are wholly devoted to brewing, and other illustrations are well chosen and satisfyingly informative, and the text is agreeably free from errors.

Together with so many good impressions, this book left only two faintly disturbing ones. Firstly one wonders if some of the detail, such as that of eighteenth-century chemical symbols, might not have been omitted to make way for further modern information of which the author clearly possesses such a fund ; secondly, at various points the author contrives to invest his text with a propaganda flavour which it does not need. These are, however, only minor features and they need not mar the pleasure afforded by a book which must otherwise have a wide appeal. A. H. COOK.

The Aromatic Diazo-Compounds and their Technical Applications. By K. H. SAUNDERS, M.C., M.A., B.Sc., F.R.I.C. Second edition. [Pp. xi + 442.] (London : Edward Arnold & Co., 1949. 50s. net.)

THE appearance of a second edition of K. H. Saunders' well-known monograph will be welcomed by chemists everywhere, for the aromatic diazo-compounds (used by the author in a generic sense) are of immediate practical and theoretical interest to almost everyone engaged in chemical work. The first edition merited high praise both for its wide scope and clear exposition of its subject, and the present volume is even better in both of these respects. The first edition was published in 1936 and it is an indication of the importance of the subject that a volume of double the size is now required to present an equally concise but up-to-date account. A glance through the present volume indicates that advances have been made in the study of every aspect of the subject, the preparation of diazo-compounds, their physical and chemical properties, their analysis and analytical uses. At the same time the technical applications of the diazo-compounds have increased both in number and variety, and renewed attention has been given to the theoretical aspects of their chemistry. Readers will note with pleasure the ample references appended to each section of the subject, even though the author warns us that the references cannot be complete even in a volume of this size.
W. BRADLEY.

The Analytical Chemistry of Industrial Poisons, Hazards and Solvents. By MORRIS B. JACOBS, Ph.D. Second edition. Chemical Analysis Series, Vol. I. [Pp. xviii + 788, with 121 figures.] (New York and London : Interscience Publishers, Inc., 1949. 96s. net.)

THE first of the interesting series of volumes entitled *Chemical Analysis*, published by Interscience Publishers, was Morris Jacobs' book *Industrial*·

Poisons, Hazards and Solvents, published in 1941. This book set a high standard which subsequent publications in the series have been hard put to maintain. It also fulfilled a long-felt want in co-ordinating under one cover the vast amount of scattered information relating to the chemical aspects of the newly awakening science of Industrial Medicine. The success of this volume was manifest by the appearance of the reprinted copies and now, after nine years, there appears a second edition, which not only makes the volume available once more, but also makes freely available some of the newer methods and ideas on the subject which have been developed during the intervening period.

As in the main industrial hazards are from an airborne source, it follows that a considerable part of the book is concerned with accurate methods of atmosphere sampling and the devices used for the purpose. The apparatus described in this volume does not differ materially from that given in the previous edition, but a useful addition is the inclusion of a description of electrostatic flocculation and the application of this technique to the collection of dusts from the atmosphere.

The increased use of Impinger Devices for the collection of particles of very low-sized diameter becomes apparent, and the Cascade Impactor, which allows of differential separation according to particle size, is briefly illustrated. In general, the chapter on Dust Estimation has been much elaborated.

The bulk of the book is made up of descriptions of possible toxic substances and the methods of analysis used for estimation after sampling. As before, this is divided into groups according to chemical composition—thus, metals and their compounds and organic substances are classified appropriately according to structure. In most cases the physiological activity and the toxicity of the substance are described, with a recommended technique for sampling and a selected method of analysis. This edition has been enlarged to include under the above groups the increased range of substances, but, in general, the older material has been retained. The chapter on Chemical Warfare agents listed in the first edition has been dispensed with and the subject matter thereof has been incorporated under the appropriate group headings throughout the book.

It is unfortunate that the vast amount of knowledge gained from the study of toxic gases which has occurred since the appearance of the first edition could not have been drawn upon, and, because of this, the value of the book is to some extent minimised.

R. F. M.

Materials of Construction : Wood, Plastics, Fabrics. By ALBERT G. H. DIETZ, Sc.D. [Pp. x + 347, with 180 figures.] (New York : D. Van Nostrand Co., Inc. ; London : Macmillan & Co., Ltd., 1949. $4.50 or 33s. 6d. net.)

PROF. DIETZ of the Massachusetts Institute of Technology has broken new ground by including in one volume information on wood, plastics and fabrics, and in showing how each can be used on its own or in combination with the others. He has written for the general engineer and user rather than for the specialist, which, in the plastics field at least, is a welcome innovation.

Almost two-thirds of the book is concerned with timber, its supply, fundamental characteristics, seasoning, fungal and insect pests, preservation, and

strength properties upon which he is an acknowledged authority. There is a lengthy and comprehensive chapter on veneers, plywood, adhesives and laminated products, and the author has logically dealt, later on, with what in Britain is called Improved Wood concomitantly with laminated plastics and vulcanised fibre.

The chapter on textile materials is short and makes only brief reference to artificial fibres, but that on the Chemistry of Plastics and Resins (prepared by W. H. Tonn, Jr.) will prove a valuable aid to those users who take more than a mere intelligent interest in their origin and general manufacture. Moulds and moulding methods are clearly described and illustrated, and the properties of plastics are adequately covered. Building or fibre boards, sandwiches, and composite materials also have a chapter.

The author gives a brief and clear account of many phenomena usually dealt with only in specialised treatises, but a student wishing to go further will wish that the bibliographies had been annotated more fully. The book has excellent diagrams, many fine photographs, and the indexing is good.

R. A. G. KNIGHT.

The Failure of Metals by Fatigue. Proceedings of a Symposium held in the University of Melbourne, December 1946. [Pp. xvi + 505, with 176 figures.] (Melbourne : Melbourne University Press ; London : Cambridge University Press, 1948. 42s. net.)

THIS volume serves to illustrate not only the way in which the fatigue properties of metals have become increasingly important as high-speed aircraft, gas turbines and so on have imposed more exacting requirements, but also the rapid growth of Australian interest and activity in the field of metallurgical engineering during recent years. In all, some thirty papers were presented at a symposium held in Melbourne in December 1946, and are now reproduced together with the ensuing discussions. Australian authors are well represented, but there are also important contributions from authorities in this country and the U.S.A. As Dr. Gough states in his foreword, ". . . no significant additions to our understanding of the basic problems of fatigue appear to have been contributed during the war years . . ." and it is not surprising therefore that the theoretical aspects of the subject are the ones least satisfactorily dealt with in the symposium. However, since the accumulation of authentic data is a necessary preliminary to the development of a satisfactory theory, the papers will be welcomed by those primarily concerned with the mechanism of fatigue failure as well as by those whose interests are mainly practical, for descriptions are given of fatigue failures experienced in applications ranging from nuts and bolts to gas turbines and from aerial telephone wires to railway axles. Due consideration is given to such factors as design, residual stress, stress concentration, notch sensitivity and material composition, which may all play important roles in determining the fatigue behaviour of a given component. Methods of measuring the fatigue strengths of metals are adequately described, and there are useful papers on the detection of fatigue cracks and on methods of measuring dynamic strain.

The volume as a whole presents a well-balanced picture of the subject and the University of Melbourne is to be congratulated on conceiving the Symposium and on carrying it through to such a successful fruition.

A. G. QUARRELL.

The Strength of Plastics and Glass. A Study in Time-Sensitive Materials. By R. N. HAWARD, B.A., Ph.D. [Pp. viii + 245, with 16 plates and 108 figures.] (London : Cleaver-Hume Press Ltd. ; New York : Interscience Publishers, Inc., 1949. 30s. net.)

THE idea embodied in the term " the strength of a material " is a comparatively simple one, though a consideration of the experimental methods of determining a " strength " reveals that in most cases the values obtained cannot be related in any simple way to the structure and properties of the material in its original state. This is true even of an ideally elastic material when strained beyond the " yield point," though the " yield strength " of such a material is directly related to its original structure, as is also the breaking strength if the material is entirely non-ductile.

It is to be expected, therefore, that a study of the strengths of plastics will reveal many effects which depend on the methods of loading and on the time during which the load is applied, since plastics exhibit slow but ultimately reversible deformations under variable loads, and also viscous flow, in addition to the instantaneous and instantaneously reversible deformations characteristic of ideally elastic materials.

Dr. Haward has made a valuable and comprehensive survey of the experimental data relating to the strength of plastics, including such allied properties as hardness and brittleness. The | experimental methods and results are examined critically and from a fundamental point of view, in so far as such examination is reasonably possible.

The chapters and sections dealing with glass, also, provide an excellent survey of the very considerable study that has been made of the strength of glass. It is not altogether clear, however, why glass should be dealt with along with plastics, in spite of the explanation offered in Chap. I. Apart from a " time-sensitive " element, the strength properties of glass are substantially those of an ideally elastic but non-ductile solid, being very similar to those of quartz ; and the " time-sensitiveness " is very much akin to the corrosion fatigue of metals.

H. M.

Glass and Glass Manufacture. By PERCIVAL MARSON. Fourth edition revised by L. M. ANGUS-BUTTERWORTH. [Pp. x + 145, with frontispiece and 42 figures.] (London : Sir Isaac Pitman & Sons, Ltd., 1949. 8s. 6d. net.)

To have kept pace with the advances of the past thirty years, each new edition of this book should have been largely rewritten rather than revised. The descriptions of pot furnaces, for example, are obviously from a much earlier edition, and tank furnaces are not dealt with adequately by modern standards. Only two of the modern Flat Drawn Sheet Glass Processes are mentioned, no reference being made to the process mainly used in this country ; but much space is devoted to the Machine-Drawn Cylinder Process which was superseded at least fifteen years ago. The chapter on Plate Glass is also out of date, and is misleading in that it implies that the Bicheroux Process is a significant advance on the Continuous-Flow Process.

All this may have been due to revision having been necessary instead of rewriting, but this does not excuse the inaccuracies in the text. Some of these are no more than over-generalisations, but there are many which are definitely misleading and erroneous, as, for example, some of the statements

concerning toughened glass (p. 28), and the apparent confusion between light
scattering (due to inhomogeneity) and chromatic dispersion (p. 111).

The geographical distribution of the industry (Chap. XIX) refers mainly
to conditions in 1939 or earlier, but it is startling to find no mention of glass
manufacture in Great Britain except in an obscure statement comparing the
prices of Japanese scientific glassware with British and American prices.

A book containing much information of interest, and pleasant to read, but
unfortunately containing much that is out-of-date, not wholly reliable, or
definitely wrong.

<div align="right">H. M.</div>

Petroleum Production. Vol. V : **Oil Production by Gas and
Flooding.** By P. J. JONES. [Pp. viii + 274, with 117 figures.]
(New York : Reinhold Publishing Corporation ; London : Chapman
& Hall, Ltd., 1948.   48s. net.)

THIS is the fifth and final volume of a series dealing with the theoretical
principles of petroleum reservoir engineering. Two different problems are
dealt with in this volume : the phase relationships of gas-oil mixtures, and
the amount of gas and oil or water and oil in petroleum reservoirs.

The separation of oil-gas mixtures at the surface and the vaporisation
of oil in the reservoir with declining pressure in the reservoir are discussed
on the basis of pressure-temperature-volume relationships and equilibrium
constants, defined as the ratio of the mole fraction of a component in a gas
phase to the mole fraction of the same component in the liquid phase.   Exten-
sive tables of the variation of equilibrium constants for temperatures of
$40°$ F. to $240°$ F. and pressures of 15 to 3000 p.s.i.a. for hydrocarbons up to
pentanes and heavier are given in an appendix.

The concept of the relative permeability of a formation to gas and oil,
and to water and oil, is discussed much more thoroughly than in previous
volumes.   Symbols are used freely, but only an elementary knowledge of
mathematics is necessary to follow the exposition.

An interesting treatment is given of the cumulative oil recovery, the
ultimate recovery, and the point of gas breakthrough in a gas injection field.
This treatment is applied to the production of oil by gas injection, from two
hypothetical radial reservoirs with gas-cap and edge-water, and one hypo-
thetical linear reservoir.

The problem of oil recovery by water flooding is dealt with in detail, with
emphasis on the percentage of oil that is recoverable under various conditions.
A basis is given for calculations on the economics of oil flooding.

The main criticisms of this volume, as with previous volumes of the
series, is that formulæ are quoted and results worked out but no indication is
given of their probable accuracy in practice.   No supporting laboratory
results or field performance data are given in the text.   Nevertheless, the
treatment is very suggestive.   In particular, the problem of ultimate recovery
of oil has not yet been solved in a satisfactory fashion, and if the formulæ
developed here are confirmed in practice, this would be an important step
forward in reservoir engineering.

The volume is not to be recommended for the general reader, but the
specialist in petroleum engineering will find the treatment useful and stimu-
lating, providing he interprets the text in the light of his field experience.

<div align="right">BEN NOBLE.</div>

American Chemical Industry. Vol. VI : **The Chemical Companies.**
Edited by WILLIAMS HAYNES. [Pp. viii + 559.] (New York : D.
Van Nostrand Co., Inc. ; London : Macmillan & Co., Ltd., 1949.
$10.00 or 75s. net.)

THIS publication is Vol. VI of a series dealing with the American Chemical
Industry. The previous volumes have dealt with the industry in time
periods. Within this framework it was necessary to trace the development
of the industry by studying various related groups of chemicals ; in some
cases the products were related chemically, as for example in the chapters
dealing with acids, alkalis and coal tar products ; in others a classification
based on use was adopted, for example in the case of fertilisers and insecticides,
and synthetic resins and plastics. Since most chemical undertakings manu-
facture products in many diverse fields, this treatment gave only a scattered
and incomplete idea of the history and development of any particular com-
pany. To rectify this the present volume has been published, dealing with
the individual histories of 219 companies up to 1948. Each company appar-
ently submitted the draft of its own history. These have been edited to
obtain some uniformity as regards length, style and content. The editor in
a foreword states that, while in the process of editing some of the life and
glamour may have disappeared from the histories, the essential facts have
been scrupulously preserved and have in the main gained in precision and
clarity. Each company is dealt with in strict alphabetical order. The
stories deal not only with the technical developments and achievements of
the companies, but also with many of the leading personalities who have
shaped their destinies. They, therefore, form a valuable and fascinating
contribution to the history of the great American Chemical Industry. The
volume has good name and products indexes and should find a place as
a useful book of reference on the bookshelves of anyone interested in American
chemical production.

<div align="right">J. D. P.</div>

GEOLOGY AND GEOGRAPHY

Principles of Structural Geology. By C. M. NEVIN. Fourth edition.
[Pp. xiv + 410, with 250 figures, 7 plates in pocket.] (New York :
John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949.
48s. net.)

THE second edition of this work was reviewed in SCIENCE PROGRESS, 31,
1936–37, p. 767. In this edition the text has been revised and expanded,
and the numerous excellent illustrations have been increased to cover the
additions to the text. In response to many requests, a new chapter has
been added on "Laboratory Exercises," which deals with the solution of
problems that arise in the field and in the preparation of reports and maps.
Graphic methods are used, including the stereographic net ; and these are
illustrated with many text-figures and seven large folding maps strapped to
the back cover. This section strikes the reviewer as one of the best on this
exacting subject that he has over seen.

The general lay-out of the book follows logically from chapters on stress
and strain in rocks and on their physical properties, through chapters on
various types of rock deformation—flexures, faults, jointing, cleavage—to

chapters on structures associated with igneous intrusion, structures in unconsolidated sediments, and the topographic effects of rock structures. The book reaches its climax with three chapters on " Some Facts, Inferences and Hypotheses regarding the Earth," (density, isostasy, earthquakes, temperature-gradient, shrinkage, compression, etc.), " Continents and Ocean Basins," and " Mountain Systems," including the relations between orogeny and epeirogeny.

These three chapters are admirably done. The reviewer feels that not only the " beginning " students, for whom the book appears to have been written, but those more advanced in the subject, will find the study of these chapters most rewarding. Excellent selections of reading references are given at the ends of the chapters which are probably more suitable for advanced rather than first-year students, as is implied in the Preface.

The style of writing is clear, and as simple and balanced as the subject allows. The book is beautifully printed and produced on good paper. The reviewer has found little to take exception to as regards its factual content. On p. 275 it is stated that the Azores and Ascension I are composed of a more acid type of rock than basalt. As a matter of fact they are both largely composed of olivine-basalt and the trachytes, etc., found in them are mainly in small domes. On p. 275 " expected " is written for " excepted," and on p. 312 " Ordovician " is misspelled.

<div align="right">G. W. T.</div>

The Geology of the British Empire. By (the late) F. R. C. REED, Sc.D., F.G.S. Second edition. [Pp. x + 764, with 26 figures, including 15 folding maps.] (London : Edward Arnold & Co., 1949. 70*s.* net.)

THE first edition of this work was published as far back as 1921. Since then there has been an enormous increase in the amount of geological work done in all parts of the British Empire (which term incorrectly includes the great Dominions). Dr. Cowper Reed had only just completed the revision of this work when he unfortunately died ; and in compliance with his wish the (late) Sir Edwin Pascoe undertook to see the book through the press. In a Note dated December 1947 appended to Dr. Reed's preface Sir Edwin stated that he made no attempt to bring the text immediately up to date, and only ventured on a few minor corrections. In his Preface to this edition Dr. Reed stated that he had revised and rearranged much of the matter, and had enriched it by personal visits to India, South Africa, Cyprus, Palestine, etc. The death of both Dr. Reed and Sir Edwin Pascoe no doubt accounts for the omission of some important recent work.

The book is admittedly a compilation, but as many of its sources lie buried in the less accessible colonial scientific journals and Government publications it has almost the value of an original work. It is especially useful for the geology of the minor dependencies of the Empire. The geology of the great Dominions is more or less covered by easily accessible regional treatises.

The method employed is to deal separately with each political unit regardless of its size, describing its physical characters, general geology, structural relations and economic minerals, but relegating the stratigraphical details to smaller type. A huge list of literature follows each section ; thus the one on Canada and Newfoundland has no fewer than 687 items ! This, in itself, is

a most valuable feature of the book. Another valuable part is the set of folding maps which appear to be original compilations by Dr. Reed.

This second edition of a standard work will be resorted to for its information, references and maps by all geologists interested in the geology of the British Commonwealth, Colonies and Dependencies. It must be fundamental for the work of the Colonial geological surveys.

G. W. T.

Physical Geography. By PHILIP LAKE. Second edition, revised and enlarged by J. A. STEERS, G. MANLEY and W. V. LEWIS, under the editorship of J. A. STEERS. [Pp. xxviii + 410, with frontispiece, 24 plates, 204 figures and 7 maps.] (Cambridge : at the University Press, 1949. 15s.)

THE revising authors and publishers are to be congratulated on this new edition of what the authors in the preface correctly refer to as a perpetual standard textbook.

The book is well produced, a joy to handle, especially when the modest (by present-day standards) cost of fifteen shillings is borne in mind.

The authors have not taken upon themselves an easy task. To revise a work so well known is to open the doors to criticism from all. They have been successful in their task and can have displeased but very few.

The chapter headings will be familiar to those generations of geographers who were nurtured on the old Lake. But new chapters have been added where new material, now within the scope of Sixth Form and first-year university students, has passed from periodical to textbook status, e.g. Part I, Chapter I, in which Air Mass and Frontal Meteorology is covered.

The other chapters are deceptive ; they contain a very large proportion of the familiar material, but have been considerably expanded by the inclusion of modern theory and further illustration, e.g. Part III, Chapter IV, Shorelines, which has been expanded to over twice its original size. This is of course in direct response to the work of two of the revising authors in the past twenty years.

The illustrations, where new, are clear and well executed. (The hachuring does not give a correct picture of the form of the ground south of the Dovey in Fig. 130. The spit takes off from the foot of the cliff which is the sole break of slope at this point.) The photographs are refreshing, particularly the cloud types.

Mistakes are few and minor in character : on p. 19 AB should read AE as it does in the first edition. It is regretted that the names of the projections used were not either listed or, better still, given on those maps which require it. The omission of the name Goodes Homolographic on the oceanographical distribution maps is all the more regrettable as it appears on the maps from which these were taken. A word of explanation regarding its slope would not have been out of place in a textbook of physical geography.

The new Lake is essential for all who would aspire to Geographical knowledge beyond the School Certificate stage.

E. H. B.

BOTANY AND AGRICULTURE

An Introduction to Botany. By J. H. PRIESTLEY, D.S.O., B.Sc., F.L.S., and LORNA I. SCOTT, M.Sc., F.L.S. Second edition. [Pp. xii + 625, with 170 figures.] (London, New York, Toronto : Longmans, Green & Co., 1949. 21s. net.)

THE appearance of this second edition will be welcomed by many teachers who, having used the original edition, will know that it is a useful and stimulating textbook. The contents, which form the basis of the first-year course at Leeds, are unusual in their scope and will probably not correspond at all closely with the courses given in other universities. The factual content is mainly confined to the Flowering Plants, but a few lower plants are described as an introduction to the reproduction of the former. Any serious student is, however, bound to benefit from the method of presentation ; from the insistence on an understanding of the three-dimensional nature of plant structures ; and from the interpretation of form and structure on the basis of development.

Causal explanations are frequently given which go beyond the ascertained facts but, as the Preface says, " No connected story can be written of the plant without connecting-links woven of speculative material." This viewpoint is defensible and a good student will gain from it if he is stimulated to confirm, or deny, the validity of the speculation. There is, however, a considerable danger that students will accept the speculations as facts, since the distinction is not always clear.

The new edition shows evidence of careful revision. An important, and useful, change has been made in the nomenclature of the vascular tissues of the stem, the use of the terms protoxylem, metaxylem and secondary xylem now being brought into line with the more classical usage of the terms. Greater precision is given to the account of apical structure by the introduction of the terms eu-meristem and vacuolating meristem. Changes, mainly in the form of additions, have been made in the chapters on physiology. The enzyme systems involved in respiration are now more fully dealt with ; so, too, are the growth substances, although the treatment of these is still rather slight.

The line drawings are excellent, but it is unfortunate that their reproduction by photolithography has resulted in some loss of quality as compared with the original edition. The photomicrographs are also good, although it may be doubted whether such illustrations as Figs. 94 and 95 will mean much to a student until he has himself observed similar preparations.

Finally one may say that all botanists will share Miss Scott's regret that the late Prof. Priestley was not able to share in the revision of this outstanding textbook.   S. W.

An Introduction to Plant Biochemistry. By CATHERINE CASSELS STEELE, M.A., B.Sc., Ph.D. Second edition. [Pp. viii + 346, with 12 figures.] (London : G. Bell & Sons, Ltd., 1949. 22s. 6d. net.)

BRITISH chemists have made notable contributions to our knowledge of plant products, whilst the investigations of Baker and Smith in Australia and of Gibbs in Canada have indicated how such knowledge may prove of value to taxonomists. In plant physiology many questions still require answers, and if the botanist is to supply these he will require an adequate knowledge of

plant biochemistry. This requirement was realised by Dr. Steele in 1934 when the first edition of her book appeared. Few were better qualified than Dr. Steele, both as a teacher and as an original investigator, to prepare a suitable text. A new and revised edition of her book has now been published which has all the merits of the first edition whilst incorporating much new work. The final section of the book dealing with the difficult problems of plant metabolism is of exceptional value. Students of botany can devote comparatively little time to the study of chemistry, and Dr. Steele has included a number of simple experiments. These are well chosen, but the reviewer is doubtful if they add to the value of the book. This can be strongly recommended, not only to students of botany, but also to honours students in chemistry, who will find therein much that is not readily available elsewhere. The book is well produced and the price reasonable. J. L. S.

Introgressive Hybridisation. By EDGAR ANDERSON. [Pp. x + 109, with 23 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 24s. net.)

HYBRIDISATION between local races of a species, between species themselves, or even between genera could be of importance in three ways. New races or species may arise by polyploidy of sterile hybrids ; types may segregate out of fertile hybrids which are adapted to some hitherto uncolonised, and perhaps new, habitat ; and genes may be transferred from one type to another without any obviously new type arising. Polyploidy following hybridisation is known to be of importance in plants, but successful new types seem seldom to originate by segregation after wide hybridisation.

The third possibility of gene transfer by " introgressive hybridisation " has hitherto received less attention. Dr. Anderson now discusses it from both the genetical and the ecological standpoints. Genetically he shows that the chromosome mechanism must lead to a strong tendency for individuals in the later generations after hybridisation to revert to the parental types, though often with a few gene differences from the parents. The need for ecological adaptation must encourage this tendency. In fact, obviously hybrid derivatives may be expected to survive only where there has been a great disturbance of habitat, as for example where man has recently been actively engaged in clearing operations. In the absence of such " hybridisation of the habitat," as Anderson calls it, reversion to parental form must be greatly speeded by the ecological selection. Yet even if only a few genes are transferred from one parent to the other in the process, introgression may well constitute a greater source of new variation than mutation within the parental type itself. Introgression may therefore be of great evolutionary importance.

The technical methods of establishing and analysing the occurrence of introgressive hybridisation are not forgotten. Indeed, Anderson shows how the characters of the second parent may be inferred from variation in the type into which introgression is occurring. These methods are perhaps at present a little crude, but refinement can be confidently expected as investigation proceeds.

Dr. Anderson has made out a case for the occurrence of introgression. He himself concludes by raising the question of how important it is. This is clearly a question meriting the wider attention which *Introgressive Hybridisation* will go far to secure. This book is one which should be read by all

interested in evolution and the properties of wild populations. It must have its interest, too, for plant breeders, as the author shows. And finally, though written by a botanist and illustrated entirely by reference to plants, it should be no more overlooked by the student of animal populations and evolution than by the student of plants.

. K. MATHER.

Chemical Activities of Fungi. By JACKSON W. FOSTER. [Pp. xviii + 648, with 35 figures.] (New York: Academic Press, Inc., 1949. 71s. 6d. net.)

THE author of this book claims that it is written as " a text for college courses at the upperclass or graduate level." It is in fact entirely unsuitable for students who have not yet developed a highly critical faculty and who have not yet acquired a good working knowledge of the original literature, for it abounds in factual errors and gives only a one-sided account of the subject. The title is misleading, for there is no consideration of the biochemistry of the higher fungi, in spite of the fact that there is an extensive literature on the subject. A chapter on " Chemical nature of the mold mycelium " omits all reference to pigments, though these may accumulate to the extent of 30 per cent. of the dry weight of the mycelium. In "The methodology of mold metabolism " the author claims that the only way to study the activities of moulds is to grow them in submerged culture with forced aeration, that is, under conditions far removed from any under which moulds normally grow. Eight of the nineteen chapters discuss the production of alcohol and the simple acids, most of the space being given to setting out the various theories, often contradictory, of the mechanism of formation, whilst scores of other interesting products of fungal metabolism are almost completely ignored. A chapter of 30 pages on Penicillin was surely unnecessary in view of the numerous existing publications on this topic, particularly as other antibiotics are entirely neglected. The book will be of use chiefly to research workers, who will find value in the lists of references to branches of the subject other than their own.

The author's style is prolix in the extreme. He could easily have compressed his material into half the space or, alternatively, could have attempted to justify his title.

The format of the book is good and few misprints have been noticed.

G. S.

The History of Sugar. Vols. I and II. By NOEL DEERR, F.C.G.I., F.R.I.C. [Pp. xiv + 636, with 31 plates, 48 figures and 8 maps.] (London: Chapman & Hall, Ltd., 1949–50. Vol. I, 50s. net; Vol. II, 55s. net.)

FOR the greater part of this century Noel Deerr has come to be regarded as the ultimate authority on all matters pertaining to sugar. The work under review is obviously the result of indefatigable research and investigation, and one of its most valuable features is the list of references that appears at the conclusion of each chapter.

The first chapter of Vol. I gives a list of sacchariferous plants and their distribution, and the next is devoted to honey and its history and development from prehistoric times. The whole of the remainder of the volume deals with the sugar cane and its products.

The author discusses the original home of the sugar cane and gives a

fascinating account of its spread to all parts of the tropical and sub-tropical regions. As he points out, the reason why sugar cane is considered to be indigenous to the South Pacific is based not only on legendary history, but also on scientific investigation. For example, in this region, cane is infested by a certain beetle borer, but this in its turn is controlled by a tachnid fly parasite—such a tripartite association indicates the lapse of thousands of years.

An account is given of the arrival of the sugar cane in India from its native home, and how, later, it spread all over the world. Evidence is produced to prove that there was no sugar cane in the Western Hemisphere before the arrival of Columbus, who brought plants from Europe on his second voyage in 1493, and planted them at Isabella, on the north coast of Hispaniola.

A chapter is devoted to the history of cane in the various sugar-producing regions, and it is interesting to note that the general pattern of development in the industry in the various regions is much the same. In the early days one particular variety, such as the otaheite cane, would hold the field for a period of many years. A particular disease or pest would then appear and compel the grower to look round for new varieties. For long *Saccharum officinarum* was considered to be infertile, but, when investigators in Barbados and in Java proved that this was not so, the way was open to the breeding of new varieties to meet the needs of any new situation that should arise. Nowadays, new seedlings are continually replacing old, and, because of their disease resistance, higher sugar content and hardiness are giving largely increased yields per acre.

The industry has always been subject to periods of economic prosperity or depression, and these have led indirectly to many improvements in cultivation methods, such as mechanisation, which has reached an advanced state in the West Indies, the use of fertilisers, the centralising of factory production, and continued technical improvements in the manufacture of sugar.

Mr. Deerr deals historically with the impact of cane on the economy of the different areas it entered. Long tables of figures summarise the sugar production over the centuries : the Jamaica figures, for example, cover the period 1697–1946, and Barbados 1698–1946.

So far as the English Colonies in the West are concerned, the author regards Barbados as the founder of the sugar industry. Apart from these Colonies, there are chapters on the sugar-cane industry treated from the historical angle of many other countries, such as India, China, Greece, Egypt, the United States, and the Colonies of other European Powers.

The second volume opens with a prolonged description of the origin and development of the slavery movement, and particularly as it was concerned with the development of the sugar industry. From time immemorial slavery had been recognised as a normal state in human society, and it must be remembered that abolition only occurred a little over one hundred years ago. With the rapid development of the sugar industry in the fourteenth to sixteenth centuries, it was understandable that resort should have been made to the importation of slave labour. West Africa was the chief source of supply for the Western Hemisphere, although it is interesting to note that some slaves from East Africa were also recruited for the sugar plantations of Mauritius. In the early days the loss of slaves during the notorious Middle Passage was heavy, but later became much less, falling to 4 per cent. The author estimates the total number of slaves recruited from West Africa during the period of some four hundred years as about thirteen and a half million.

The chapters devoted to the rise and fall of the slave trade and the manage-
ment of sugar plantations during this period make fascinating reading and
enable us to get a fair picture of the conditions of life at that time.

After the close of the Napoleonic Wars sugar reached the fantastic price of
97s. per cwt., but a rapid fall then set in to a minimum of 23s. in 1931. This,
combined with the emancipation of the slaves, led to hard times, and many
sugar estates became bankrupt. This period is discussed in the chapter
entitled " The English Colonies after Emancipation." Subsequent chapters
deal with the efforts made to cope with these difficulties by means of free
immigrant labour and later by means of indentured Asiatic labour.

Mr. Deerr mentions the stimulus afforded to beet sugar production in
France during the Napoleonic Wars, when the country was blockaded and
could not import cane sugar. Later, as we know, beet sugar under the
Bounty system became a serious competitor. Further chapters are devoted
to the beet-sugar industry, and to the sugar duties in England, and to the
Bounty system. The effect of the Bounty system whereby beet sugar could
be sold at less than the cost of production had, of course, a severe impact on
the sugar-cane plantations, and brought that industry to the verge of ruin,
from which it has taken a long time to make a full recovery. It is nevertheless
interesting to note that sugar cane still provides more of the world's sugar,
for in 1939–40, 67 per cent. came from this source, and all other sources, of
which the beet plant was by far the greatest, made up the remainder.

A chapter is devoted also to minor sources of sugar, of which the Maple
sugar industry of Canada and the brown sugar made from the sap of the
Borassus Palm in southern India are the most important.

A full discussion of the prices and values of sugar during the historical
period follows and a final chapter is devoted to the technological side. An all
too brief account is given of the primitive methods of extraction and the
gradual evolution to the elaborate processes in use at the modern factory.

Both volumes are profusely illustrated, and there are many reproductions
of old woodcuts and portraits, which add greatly to the interest and historical
value. A comprehensive index is included at the end of Vol. II.

The amount of research and of knowledge that has been incorporated
into this work is very obvious and shows the versatility of the author and his
great interest in the subject. His *History of Sugar* is assured of a place in
any library.

G. E.

The Coming Age of Wood. By EGON GLESINGER. [Pp. xvi + 279,
with 13 illustrations.] (London : Secker & Warburg, in association
with Sigma Books, 1950. 12s. 6d. net.)

DURING the last ten years so much has been heard in Britain of the world's
timber shortage that it is a pleasant surprise to discover an author who takes
an optimistic view of the future of wood.

While the author lays no claim to a specialist knowledge of wood, his work
for many years has brought him into intimate contact with this important
commodity, particularly as concerns its political and economic aspects, and
he is probably in a better position than the technologist to write extensively
on the subject.

Dr. Glesinger foresees an enormous future for timber, not so much as
timber but as the raw material for food, fuel, plastics, textiles and chemicals.

He sees a time when so valuable a product will not be wastefully exploited, when sawdust and other present-day waste will be as valuable as the rest of the tree trunk, a time when the whole of the tree will be put to use. Then, given a sane world economy, it should be possible to produce trees enough to supply the needs of the human race in many directions and that, continuously, year after year.

Although many of the developments which the author envisages are not likely to materialise in the near future, it is difficult not to believe that his optimism is justified. His figures will probably be accepted with reserve—we have learnt in the last few years how much reliance to place on official figures and statistics—but the present and potential uses of cellulose are large and cellulose constitutes about 50 per cent of the wood substance, while developments in the utilisation of lignin, which forms some 25 per cent of the woody material, may be expected in the near future. Such developments, however, presuppose considerable advances in our knowledge of chemistry and, simultaneously with this increase of knowledge, man may learn to imitate the chemistry of the living tree and to produce the substances which he needs—sugars, cellulose and the like—from water, carbon dioxide and other chemicals, as the tree has been doing for ages past. If this feat is accomplished, trees may still be required as a source of wood for joinery and constructional work, or perhaps by then the use of wood as a structural material will be obsolete and trees will remain, where there is room, merely to satisfy our æsthetic sense. F. W. J.

Soils : Their Origin, Constitution and Classification. By G. W. ROBINSON, C.B.E., Sc.D., F.R.S. Third edition. [Pp. xxii + 573, with 9 plates and 22 figures.] (London : Thomas Murby & Co., 1949. 32s. net.)

NOT every author of a successful scientific book has been able to meet the demands for new editions as the years go by without appreciable change in the character of the work and without increase to a size not contemplated at the outset. So far, however, Prof. Robinson has maintained the original character of his book and yet, without undue increase in size, has made real and important revisions that abundantly justify this new edition.

At the outset it was the author's endeavour to deal with soil formation and soil material and the properties of soil profiles in such a way as to present his own conception of the subject of Pedology and its problems. This object is still achieved, and one can only hope that the rather vague suggestion in the Preface of this new edition that at some future time the book may have to be divided into two volumes will not vitiate its original character, which is so far kept splendidly intact.

The original chapter on Pedogenic Processes has become two chapters, with much more about Profile Development. There are a few small, but very important, additional paragraphs on the pH of soil and these should be read by everyone who inclines to think of the pH of a soil as a real and absolute property. Structure receives some additions and the Soil Survey Chapter has a brief but useful section on Land Classification, introducing the important work of Dudley Stamp.

At other points too the book is well revised, and this edition should greatly enhance the usefulness of a book long established as invaluable to students, teachers and research workers. N. M. C.

BIOLOGY

* **Biology and its Relation to Mankind.** By A. M. WINCHESTER, Ph.D. ,
[Pp. xii + 777, with 382 figures.] (New York : D. van Nostrand Co.,
Inc. ; London : Macmillan & Co. Ltd., 1949. $5.25 or 27s. net.)

THIS is a textbook of Biology for first-year students in Colleges and Univer-
sities of the United States and Canada. As its title suggests, it is written
with special reference to the relation of Biology to Mankind.

The treatment is unusual. The first section of the book is a survey of
some of the basic principles that underlie all biological considerations, the
first chapter including a consideration of scientific method. This valuable
introduction is followed by a survey of the plant kingdom, with slightly more
detailed work on the higher plant. Then the animal kingdom is reviewed,
leading to much more detailed treatment of the biology of Man. Chapters
are devoted to important divisions of biology—microbiology, heredity and
evolution—while the book ends with an account of the work of some of the
founders of Biology.

The book is most readable, and throughout difficult concepts are explained
by everyday examples. Definitions are clear and simple ; new terms are
given in black type—but there is not too much of this. Diagrams are excel-
lent, large and well labelled. The large number of excellent photographs
enhance the value of the book.

While the book is not suitable as a textbook for candidates preparing for
Higher Certificate and those taking a first-year course at British Universities,
it is one which should be in every Sixth Form and Training College library.
It will also be useful to the teacher of General Science and to the layman who
needs a fascinating introduction to Biology, for it presents a broad survey of
the field of Biology in a way which should encourage and stimulate the reader
to further work.

A few teleological statements are made. The formaldehyde hypothesis
is accepted as explaining the way sugar is formed in the green plant, and the
method of spore dispersal in the Fern is not in keeping with the results of
observation, but for a book of this size errors seem to be few.

J. H. PHEASANT.

Fiches d'Identification du Zooplancton. Publiées sous la direction de
M. le Dr. P. JESPERSEN et M. F. S. RUSSELL. Conseil Permanent
International pour l'Exploration de la Mer. [Sheets 1–17.] (Copen-
hagen : Andr. Fred. Høst & Fils, 1949. Kr. 10.–.)

THIS collection of loose folded sheets, in a card cover, is the first-fruit of a
recommendation by the Plankton Committee of the *Conseil International*.
In the words of the Prefatory Note : " These sheets are not intended to be
short cuts to identifications, but they are to prevent unnecessary waste of
time and possible introduction of errors by plankton workers who cannot
be specialists in every group."

Each sheet has been prepared by an expert in the group concerned, but
a very satisfactory degree of uniformity has been obtained. Thus, although
the language used is sometimes English, sometimes German, the extremely
practical keys to identification are illustrated by uniform line drawings which
bring out admirably the salient features of structure upon which the key
depends. As well as the key there is a mass of useful data on each sheet :

there are tables of the distribution of the various forms in the North-West Atlantic (to which the work is confined) and a bibliography of reliable references on structure and systematics, and of select references on general biology.

The coverage of each sheet is, of course, determined by the variety of forms to be classified. Thus in the present 17 sheets the Chætognatha, Cladocera and Appendicularia are completely covered in one sheet each. Two sheets are devoted to the Thaliacea : one to the Salps, one to the Doliolids. The Ostracoda are also completely covered, and the remainder deal in part with the Hydromedusæ, Pteropoda and Copepoda.

The value of this work to marine biologists needs no emphasis, but it will also be of great help to those general zoologists who make use of plankton samples as means of familiarising themselves with the variety of marine life and the principles of practical systematics. It is to be hoped that the series will soon be completed, for the sheets in their present condition will not long survive the rough usage of the laboratory, and librarians and others will wish as soon as possible to have them bound or protected in some other way.

W. H.

The Story of Animal Life. By MAURICE BURTON, D.Sc. With special articles contributed by Zoologists of various countries. Vol. I : **The Framework of Animal Life ; Invertebrates.** Vol. II : **Vertebrates.** [Vol. I : pp. xii + 381 ; Vol. II : pp. viii + 423 ; with over 1000 illustrations.] (London : Elsevier Publishing Co., Ltd., 1949. 63s. the set.)

THESE two volumes form by far the best picture-book of the animal kingdom that has appeared in recent years. The illustrations are all from photographs excellently reproduced on good-quality glossy paper, a few of them in colour. The many photographers who have contributed their work are evidently experts, for the majority of the pictures are of living animals admirably illustrating their natural habit, and often showing specially interesting features of their behaviour captured by extreme skill and patience. The typography and design of the book are admirable, and it is remarkably free from errors of the press since, more shame to us, it was set up and printed in the Netherlands.

The text illustrated by the pictures consists first of a series of general chapters on topics such as " The Origin of Life " and " The Background of Life." In these the reader is gently introduced to modern views in fields such as that of the relation between living and non-living matter, and that of the inter-relations of animals with each other and their environment in natural populations. The rest of the volumes then deals systematically with the animal kingdom, in an evolutionary progression. Any possible monotony in this style of treatment is dispelled by the ingenious insertion of short articles by specialists, dealing with some particular feature of interest in an animal or group of animals. Thus we find, for example, at appropriate points, articles such as these : Swinton on " Living Fossils," Ommanney on " Coral Reefs," Manton on " *Peripatus*," Carpenter on " Protective Colouration in Insects," Bertin on " Fish Migration," Nissen on " The Psychology of Apes." The quality and accuracy of the work indicated by the names of these authors is fully maintained in the general text, for which Dr. Burton is chiefly responsible.

To browse through this work should give pleasure to any reasonable human being. Children will be delighted with the pictures, though the text in places

may make heavy going—but does this really matter ? A parent without zoological training who shrinks from the prospect of explaining some of the passages should remember that children delight in the magic of unfamiliar words ; Maggie Tulliver, aged nine, loved to read Goldsmith's *Animated Nature*, and how much lighter is Burton's prose !

This is definitely a book for personal possession ; there is too much in the text and pictures for absorption at one sitting, and it will be consulted rather in the armchair than in the library.

<div align="right">W. H.</div>

The Oxford Junior Encyclopædia, Vol. II : **Natural History.** Volume Editor, Dr. M. BURTON. [Pp. xvi + 486, with 8 coloured plates, 376 photographs and many figures.] (London : Oxford University Press, 1949. 30s. net.)

THIS volume was sent to me to review. I have done more, I have used it for reference and so speak with conviction when I pronounce it to be excellent. If the other volumes come up to the standard of this, the second of the series of twelve, the encyclopædia should be available in every library.

The arrangement is unusual, for each volume will deal with one subject group, and the alphabetical arrangement (from A to Z) makes the volume independent. This seems a most effective treatment and enhances the attraction of the work.

Natural History is such a wide subject that a single volume is bound to have its limitations, but it is obvious that very great care and skill have been devoted to the selection and compression of the material. As stated in the preface, the decision to insert or omit has been arbitrary and personal preferences are bound to query the wisdom of some decisions ; for example, I should have liked to see references to the work of Darwin and Mendel, if only as cross-references to the volume on *Great Lives*.

The avowed aim in the production of this encyclopædia, that it should train children to use books of reference, has been carried out so successfully that no school library should fail to grasp the opportunity thus afforded. Let me add that this does not mean that its use should be confined to school libraries, for no grown-up need be ashamed to be seen turning to its pages for reference.

One or two details require revision and I feel that some of the lavish display of photographs could be better produced. Perhaps this may be possible when a second edition is called for, a form of appreciation which is richly merited, for both authors and publishers are to be congratulated on such a notable production.

<div align="right">J. E. ROBERTS.</div>

PHYSIOLOGY, BIOCHEMISTRY AND MEDICINE

How Your Body Works. By GEOFFREY H. BOURNE, D.Sc. (Western Australia), D.Phil. (Oxford). [Pp. xvi + 228, with 16 plates and 91 figures.] (London : Sigma Books, Ltd., 1949. 12s. 6d. net.)

AN increasing number of books on Elementary Physiology have recently been published. This, it is to be hoped, signifies the wider recognition of physiology as an important subject for primary and modern schools.

Dr. Bourne's book, whilst giving a simple and generally adequate account

of the functions of the human body, has an attractive and useful feature in its historical approach to the subject. He shows its progress from very ancient times, when for the study of the body observation and speculation were its main tools, to the present, when the addition of the experimental method has resulted in advances of knowledge which may rightly be described as spectacular. This historical approach serves the author well in some of the sections, particularly those relating to the blood, circulation and respiration. As, however, the size of the book, in spite of the new material added, has been kept to the limits of an ordinary elementary textbook, some of the other systems of the body are necessarily more slightly dealt with.

A few minor corrections are needed in a new edition, which it is to be hoped may soon be called for. The suggestion is made that the " taste buds " are the only receptors for the sensation of taste, and that they are found all over the tongue, instead of being present only in very definitely localised areas. Edkins' coining of the word " gastrin " for the excitant of the flow of gastric juice is ascribed to Bayliss and Starling, and the word " dilation " occasionally gets slipped in for the more correct form " dilatation."

The historical approach gives this particular textbook an added value and interest, not only to those reading this subject for the first time, but perhaps even more to those who already have some familiarity with it.

W. C. C.

Recent Advances in the Physiology of Vision. By H. HARTRIDGE. [Pp. xii + 401, with 236 figures.] (London : J. & A. Churchill, Ltd., 1950. 25s. net.)

DURING the last few years Prof. Hartridge has, both in his writings and in his lectures, been actively challenging many of the generally accepted theories of vision. The present volume provides him with yet another platform from which to expound his iconoclastic ideas and the reader's reactions to the book will almost inevitably be coloured by his reactions to those ideas rather than to the factual material reported in the book.

This is perhaps unfortunate, since a considerable body of data has been collected, by means of which a useful view of current research in visual physiology can be obtained. This includes electro-physiological research, eye movement studies, adaptation experiments, the measurement of the dimensions of the eye by the X-ray method, the investigation of the directional effect of the retina, the measurement of the spherical and chromatic aberration of the eye, colour perception, visual acuity, the effect of age on visual performance, and so on. Prof. Hartridge has thus had a wealth of material to draw on and he has in many cases referred to researches published as recently as 1949.

He might, indeed, have been more selective in the material he used, since he rarely attempts to assess the reliability of the various experimental techniques of different research workers. On the other hand, he is altogether too critical of their theoretical views and too dogmatic in the expression of his own. Moreover, Prof. Hartridge's criticisms often seem to arise from a failure to understand the significance of the results which have been reported.

As an example, he has evidently not grasped the distinction between the spectral coefficient curves, which give the proportions of the matching stimuli required to match the colours through the spectrum, and the spectral mixture curves, which include the amount of light at each wavelength in a

given spectrum. He may not be alone in this difficulty, but, until he has mastered the data, he is hardly in a position to criticise their interpretation. His queries on p. 212, for example, and much of his discussion of the colour mixture data of anomalous trichromats, illustrate his confusion.

The book certainly leaves the reader with the impression of a vigorous mind actively probing in all directions for clues to a fuller understanding of the visual processes, but only time will show whether the volume is more than an ephemeral contribution to the subject of vision.

W. D. WRIGHT.

Outlines of Biochemistry. By Ross AIKEN GORTNER. Third edition, edited by Ross AIKEN GORTNER, Jr., and WILLIS ALWAY GORTNER. [Pp. xvi + 1078, with 125 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 60s. net.)

As the field of study to be covered by the biochemist continues to expand, it becomes increasingly difficult for any single textbook to deal adequately with every sector. In spite of its size, Gortner's *Outlines of Biochemistry* has generally been regarded as composed of three monographs on colloids, proteins and carbohydrates respectively. The rather unique selection and arrangement of subject matter is treated primarily from the point of view of the agricultural chemist.

The new edition of this standard work has followed closely upon the lines laid down earlier. The additional chapters on special subjects have been largely retained, but there has also been a general tendency towards a more balanced presentation. Thus, although the new edition is even longer than the previous, somewhat less space has been devoted to Colloids. Most biochemists will welcome this change and some perhaps would approve even further pruning. The section on Proteins remains much the same, while the space devoted to Carbohydrates and Related Substances has been extended, mainly by the addition of a chapter on metabolism.

While the first and second editions were written almost exclusively by the original author, the revision of the text for the present work has been entrusted to no less than ten sub-editors, nearly all of whom were associated with the late Ross Aiken Gortner. In addition, some portions of chapters on special subjects have been rewritten by experts in the various fields. This division of labour has generally been a success and many of the individual subjects have been brought well up to date.

Compared with earlier editions, the treatise on Colloids appears to have been changed least, presumably because of the fundamental nature of the subject. In assessing the value of this section, it should be realised that the book was originally written for students of agriculture, who perhaps had received less training in the basic sciences than is normally the case in this country. To fill such a gap in the student's curriculum, this section can be confidently recommended.

The chapters on Proteins have been generally brought into line with modern thought on this subject and include references to a representative selection of more recent research, especially in the fields of the amino-acid composition and the biological reactions of proteins.

It is in the treatment of the Carbohydrates, however, that most readers will find the book to reach the very highest standard. Carbohydrate chemistry may be mentioned specifically. The sections dealing with starch and

other polysaccharides and the utilisation of sugars by micro-organisms should also prove especially useful.

In contrast with textbooks on the medical aspect of Biochemistry, special plant topics are dealt with in more than usual detail, including excellent chapters on lignins, tannins, chlorophylls and plant pigments. A combination of *Gortner* with a modern textbook on nutrition and a monograph on enzymology and intermediary metabolism should meet practically all the needs of the advanced student.

C. LONG.

Hematin Compounds and Bile Pigments. By R. LEMBERG and J. W. LEGGE, M.Sc. [Pp. xxvi + 748, with 128 figures.] (New York and London : Interscience Publishers, Inc., 1949. 120s. net.)

THE publication of this book, which is as wide in its scope as it is comprehensive in detail, is a major event in the biochemical world. The entire field of hæmatin pigments and their natural breakdown products is covered, from physical and chemical studies of their constitution, to biosynthesis, catabolism and function. Not only are the main classes of pigments reviewed (porphyrins, bile-pigments, hæmoglobins, hæmatin, cytochromes, catalase and peroxidase), but many valuable sections on borderline subjects such as hydrogenase, anæmias and chlorophyll have been introduced. In books of this nature it all too frequently happens that the subjects in which the authors have been actively interested are given the greatest prominence, while other fields receive inadequate or unbalanced treatment. While Dr. Lemberg's outstanding contributions to the field of bile-pigments lend interest to the masterly presentation of this involved subject, the authors have, through their inexhaustible diligence in surveying and assessing published work, given the stamp of authority to each chapter of the book. The bibliography of over 3000 selected references is an indication of the Herculean task that this book represents. Time and again, when the authors feel that the present position in a particular specialised field is unsatisfactory, they bring forward their own original and often stimulating views, and in this way they make valuable contributions to such matters as the mechanisms of enzyme action and the biosynthesis of porphyrins.

A problem that faces any writer on this subject is that of nomenclature. There are broadly speaking two accepted systems, the classical one which arose before the chemical compositions were understood, and the newer one which is largely of American origin. Thus while the former makes use of hæmoglobin (ferrous) and methæmoglobin (ferric), hæmochromogen (ferrous) and parahæmatin (ferric), the latter introduces the prefixes ferro- and ferri- before both hemoglobin and hemochromogen. Drs. Lemberg and Legge now use a third system in which the ferrous and ferric forms become hemoglobin, hemochrome and hemiglobin, hemichrome respectively, while hemo (no italic) indicates both hemo and hemi forms without discrimination. Apart from objections to hemi, the risk of confusion between homo and hemo is obvious and is in fact exemplified many times in this book. Whether the introduction of these new terms can eventually reduce the present confusion is to be doubted, but nevertheless they do not in themselves detract from the value of the book. In fact, the number of errors is remarkably low. The definition of the absorption constant β requires correction, as does also the immediately following conversion factor which should read 0.434×10^{-6}

(p. 363). How serious the latter error may be depends upon the extent to which the authors themselves may have used the factor. In spite of the recent work of A. Albert on chelation, diethyldithiocarbamate is still widely accepted as a specific inhibitor of copper biocatalysis (p. 376) : a point which might receive criticism.

Problems of biological pigments are today being attacked by a multiplicity of methods which derive from many branches of science. It is for this reason that the book, in presenting a balanced picture to the research-worker, teacher and student will become a leading authoritative work of reference. The authors are to be congratulated on a work which is truly outstanding.

E. F. H.

Multi-Enzyme Systems. By MALCOLM DIXON, Ph.D., Sc.D., F.R.S. Four lectures given to University College, London, in May 1948. [Pp. viii + 103, with numerous figures.] (Cambridge : at the University Press, 1949. 7s. 6d. net.)

RECENT important advances in our knowledge of the enzymes concerned in hydrogen- and phosphate-transfer have enabled biochemists to build up and study *in vitro* the behaviour of an increasing variety of multi-enzyme systems. From the important metabolic transformations thereby achieved there has resulted a deeper understanding of the mechanisms of energy liberation, transfer and utilisation which are operative in the living cell. These developments in enzyme biochemistry have now been admirably summarised by Dr. Dixon. Starting with a brief description of the nature of enzymes, there is built up a clear picture of the functioning of multi-enzyme systems in the respiratory release of energy and in the utilisation of this energy for biosynthesis and the performance of mechanical work. In this account frequent use is made of hitherto unpublished data from the author's own laboratory. The book is notable for its lucid treatment of the rH scale and for its introduction and profitable use of an rP scale. The omission of all citations to original papers is justified by the author on the grounds that it is impracticable to give a complete bibliography. Selected references to more detailed and specialised reviews might, however, have enhanced the value of the book to students. Very little saving of space, but some detraction from the otherwise very readable text, results from employing the numerous abbreviations now in vogue to designate metabolites.

H. E. STREET.

Recent Progress in Hormone Research, Vol. IV. Edited by GREGORY PINCUS. [Pp. viii + 529, with numerous figures.] (New York : Academic Press, Inc., 1949. 66s. 6d. net.)

THIS volume contains the substance of the papers presented and a record of the discussion which took place at the Laurentian Hormone Conference held at Franconia, New Hampshire, U.S., in September 1948. The new meeting-place of the Conference made possible a somewhat larger attendance than in previous years, and, as indicated by the discussion which followed each communication, the larger numbers did not in any way diminish the keenness of the discussion.

The sections and titles of individual contributions are as follows : Section I, " Steroid Hormone Metabolism *in vivo* and *in vitro* "—" Some aspects of progesterone metabolism," by G. F. Marrian ; " The metabolism

of the estrogens, Part One," by R. D. H. Heard; "The metabolism of the estrogens, Part Two," by R. D. H. Heard and J. C. Saffran; "The metabolism of androgens by tissues," by Leo T. Samuels; "The metabolism of estrogens with particular emphasis on clinical aspects," by Albert Segaloff. Section II, "The Role of Hormones in Tissue and Body Metabolism "—"The antihormone problem in endocrine therapy" by James H. Leathem; "Integration of the effects of adrenal cortical, thyroid, and growth hormones in fasting metabolism," by Abraham White; "The alterations in metabolism incident to administration of insulin, adrenalin, and thyroid substances, studied with the aid of isotopes," by Dewitt Stetter, Jr.; "The pancreas as the guardian of the liver," by C. H. Best; "Metabolic changes in man following adrenal and pituitary hormone administration," by George W. Thorn and Peter H. Forsham. Section III, "Neurohumoral-Hypothalmic Relationships "—"Adrenal function in mental disease," by Gregory Pincus, Hudson Hoagland, Harry Freeman, and Fred Elmadjian; "Manifestations of altered autonomic and humoral function psychoneuroses," by R. A. Cleghorn and B. F. Graham; "Effects of hypothalmic lesions on water and energy metabolism in the rat," by James A. F. Stevenson. Section IV, "Thyroid Physiology and Function "—"Physiologic reactions of the thyroid stimulating hormone," by Rulon W. Rawson and William L. Money; "The metabolism of iodine in man as disclosed with the use of radioiodine," by F. R. Raymond Keating, Jr., and A. Albert; "Radioiodine as a diagnostic and therapeutic tool in clinical medicine," S. M. Seidlin.

On this occasion the influence of steroid hormones is somewhat less evident than on previous similar occasions, but the review in Section I by experts on the recent work on the Metabolism of Androgens and Oestrogens makes fascinating reading, both for the experimentalist and the clinician. The discussion in this section seems to have been particularly lively.

In Section II, the Role of Hormones in Tissue and Body Metabolism is a subject which necessarily leads to less conciseness than does a discussion of metabolism of steroid hormones, but again the individual papers are of great interest, and the discussion, often extremely critical, of absorbing value to those who were unable to be present at the Conference.

The rise of interest in the nervous control of hormonal functions and the relationship of hormones to the nervous system in general is reflected by the three papers read in Section III. Finally, in Section IV, recent work on the metabolism of iodine, made possible in particular by the use of radioiodine, has been interestingly surveyed, although the literature in this somewhat complex field is by no means fully treated in those three rather specialised papers.

Once again it can be said that this volume is one which every investigator in the hormone field must possess. Like the previous volumes in this series, this book is one of great value to the actual worker in the field, and of substantial interest to those who have already some knowledge of the subject of hormones either from the point of view of the clinician or as a laboratory experimentalist.

Dr. Pincus plays a major part in the arrangements for the Laurentian Hormone Conference and he is not only to be congratulated on his success in that role, but also on his diligence and ability in facing with such valuable results the arduous task of arranging and editing this volume.

F. G. Y.

Selective Toxicity and Antibiotics. Symposia of the Society for Experimental Biology, No. III. [Pp. viii + 372, with 6 plates and numerous figures.] (Cambridge : at the University Press, 1949. 35s. net.)

THIS book, which is well printed in the customary manner of the Cambridge University Press, contains twenty-two papers read at a Symposium in Edinburgh in July 1948.

The nature of the book may not be self-evident from its title. Two papers contain straightforward accounts of antibiotics from *Bacillus polymyxa* and from hops, and two others deal with effects of antibiotics and animal secretions on the balance of nature. M. R. Pollock describes the inhibitory and stimulatory effects of fatty acids on certain bacteria. The book is largely concerned, however, with mechanisms by which various drugs—antimalarials, insecticides, herbicides and antibacterial substances—may exert their toxic effects.

It is emphasised that many drugs whose specificity leaves much to be desired in practice are nevertheless selective ; they cannot be dismissed as general protoplasmic poisons. A. R. Trim and A. E. Alexander consider how physical properties may affect the ability of a drug to penetrate or disorganise cell membranes, and both they and A. Albert draw attention to the formation of mixed micelles as a cause of the interference of some drugs with others. R. A. Peters discusses the effect of BAL and arsenicals on sulphydryl enzymes. D. D. Woods and R. H. Nimmo-Smith describe recent work, which has firmly established Woods' theory of the mode of action of the sulphonamides, and E. F. Gale reviews his investigations on the action of penicillin. Theoretical considerations relating to the design of inhibitors based on essential metabolites are put forward by H. N. Rydon. There is a lucid description by C. N. Hinshelwood of his views on bacterial adaptation ; it is a pity that the book contains no exposition of other theories about this phenomenon.

This symposium reveals how far, with a few exceptions, a precise understanding of selective toxicity has lagged behind the ability to discover new drugs of practical importance. The book should be valuable to all those interested in the complexities of drug action.   E. P. ABRAHAM.

Industrial Hygiene and Toxicology. Vol. II. Edited by F. H. PATTY. [Pp. xxviii, 533–1138, with 7 figures.] (New York and London : Interscience Publishers, Inc., 1949. 120s. net.)

HAVING covered the broad and general aspects of industrial hygiene in Vol. I of this monumental work, the contributors to Vol. II deal more specifically with industrial hazards and the agents which produce them, including their properties, physiological action, analytical methods and permissible concentrations, while a final chapter describes the recognition and control of potential exposures in practically every known industrial process.

Some idea of the task undertaken, and on the whole magnificently fulfilled, can be gained from the fact that, under the heading " Halogenated Hydrocarbons " alone, forty-three compounds are described. The number of toxic agents included in the first nineteen chapters is in fact so great that in some instances the account suffers a little from the inevitably necessary curtailment, but the uniform arrangement of headings and the list of references appended to each subject make an extremely valuable foundation upon which those who require a fuller account can build.

The chapter on "Industrial Lead Poisoning," by Dr. Robert A. Kehoe, does not suffer even from this slight disability. Both the engineering and medical aspects are treated in full detail. It is interesting to note that in the United States the trend in evaluation of load exposure is increasingly towards lead analyses of blood and excreta and away from the estimation of punctate basophilia in the blood.

Among "The Metals," described by Dr. F. Heyroth, are included many of those which are comparatively rare in industrial use, such as germanium, osmium, palladium, ruthenium and vanadium, about which little information has hitherto been available without a time-consuming search through the literature.

A large section is devoted to industrial solvents, and a vast amount of information is compressed into it ; the tabulation which the compression has necessitated makes reference easy, and an admirable feature is the translation of milligrams per litre into parts per million, so that the maximum allowable concentrations can be readily recognised in either form.

The last chapter, "Potential Exposures in Industry," by Dr. Patty and Dr. F. R. Holden, is especially valuable because it gives a great deal of information on actual industrial processes in a form which is not readily available in any other publication of this kind.

The various industries are listed alphabetically and each contains a description of the technical manufacturing process and of the associated potential hazards. Thus, under "Automobile Manufacture," the reader is referred to headings such as Abrasive Blasting, Anodising, Battery Manufacture, Electroplating, Foundry Operations, Forging and Iron Working, Garages, Grinding and Polishing, Heat-Treating, Industrial X-ray, Lead Workers, Metal Cleaning, Metalising, Motor Testing, Painting and Decorating, Pickling, Plastics and Resins, Radio Manufacture and Repair, and Welding. Since the agents producing hazards in each of these separate industries have already been described in detail under their appropriate headings in previous chapters it is possible, by combining the two sources of information, to obtain a comprehensive idea of why and how specific hygienic precautions should be taken in the entire vast field of modern industry.

ETHEL BROWNING.

Bacteriological Technique. By W. W. W. McEWEN, A.I.M.L.T., F.R.M.S. With a Foreword by PROFESSOR SIR ALEXANDER FLEMING, F.R.S. [Pp. viii + 286, with 70 figures, including 4 plates.] (London : J. & A. Churchill, Ltd., 1949. 15s. net.)

THIS small book is intended for student technicians. It describes the general organisation and equipment of a bacteriological laboratory, the care of apparatus and animals ; general bacteriological techniques and the preparation of culture media and stains ; the various types of filter and microscope. The procedures used in the examination of tuberculous sputa, throat swabs, faeces, milk, water, shell-fish and skin scrapings and hair are dealt with.

The advice on laboratory stock-keeping is clearly written and of great value and the description of a laboratory is helpful. The best chapters are those on the examination of sputum for tubercle bacilli, and on the use of the microscope.

Unfortunately there are defects in this book ; for example, the section on the preparation of media does not mention the commoner tellurite media for

the diphtheria group ; the desoxycholate-citrate formula is not that now generally used, and the rarer media have a disproportionate amount of space and the commoner insufficient detail. Anaerobic culture methods contain no mention of cooked meat medium or the cylinder as a hydrogen source, and the indicator is too briefly described.

The principles applying to common apparatus (incubators, baths, sterilisers and the centrifuge) are either not dealt with or are too briefly described.

The most serious omissions and lack of detail apply to the technique of examining throat swabs and faeces, the examination of urine, pus, nasal and prenasal swabs and the C.S.F. being omitted entirely. The technician should know this in considerable detail and also the everyday procedures of antibiotic sensitivity tests and serum levels, which receive no mention.

However, the book contains some useful information ; there is a great need for a book of this kind to give sound and detailed guidance to the technician on all matters applying to bench-work and laboratory maintenance.

W. D. LINSELL.

Anæsthetics and the Patient. By GORDON OSTLERE, M.A., M.B., B.Chir., D.A. Sigma Introduction to Science 15. [Pp. 166, with 4 plates and 6 figures.] (London : Sigma Books Ltd., 1949. 7s. 6d. net.)

THIS small book about anæsthetics is written for the layman. Most of us fear losing consciousness when we take an anæsthetic ; we fear the unknown ; but we forget that we become unconscious when we sleep. Believing that knowledge will go a long way to dispel such fears, the author, who is a young doctor specialising in anæsthetics, sets out to enlighten his readers with an account of the history of modern anæsthesia, descriptions of modern anæsthetic methods, and an explanation of how anæsthetic drugs work in the human body. The progress which anæsthesia has made during the last thirty years ranks high amongst the many advances which have occurred in medicine since the first world war. The use of curare, the arrow poison discovered by Sir Walter Raleigh in the sixteenth century, enables abdominal operations to be performed without the disadvantages of deep anæsthesia, and is an example of this progress. To a large extent the author has succeeded in his object, and in every page the reader will find much to interest and intrigue him, written in clear and simple language ; all perfectly understandable to the non-medical mind.

So far, so good ; but the author pursues further his theme " Anæsthetics and the Patient." For the nervous man who is likely to have to face an operation in the near future a knowledge of how the anæsthetic drugs work and of the advantages of modern methods may give a large degree of assurance, but, if he reads on, he will learn much about the complications which may occur as a result of taking the anæsthetic. This knowledge may well bring him to the operating theatre in a far from tranquil state of mind; and it doubtless will add to these fears if he carries in his mind the picture (Plate IV) of an opened abdomen.

As in his other excellent monograph which is written for medical students, the author shows a genius for putting complicated facts clearly. The book is well written, amply illustrated, and scientifically correct. For many it is one they will much enjoy reading.

S. R.

PHILOSOPHY AND HISTORY OF SCIENCE

The Unitary Principle in Physics and Biology. L. L. WHYTE. [Pp. x + 182.] (London : The Cresset Press, 1949. 12*s.* 6*d.* net.)

IN this book Mr. Whyte attempts to use what he calls the "unitary principle," to which he gives a definite meaning, to show how physics, biology, psychology and other possible natural sciences could be brought within one system of unified scientific theory. This he proposes to approach through a critical analysis of the implicit assumptions and basic principles of existing sciences, so as to reach "the indispensable criterion of scientific knowledge, the most general assumption which could provide the basis for a science." Only "through the discovery of a universal method of thought providing the basis of a unified humane science" does Mr. Whyte believe civilisation can be saved. This method, he suggests, is provided by his unitary principle, and the bulk of the book is devoted to the illustration of its application, first, briefly, in physics and then, in greater detail, in biology, leading finally to a theory of organism.

As to basic principles, Mr. Whyte says : "In facing the unknown the theorist has one weapon : his conviction that nature is simple, that a universal order awaits discovery." This conviction, he adds, "may be an illusion, but it is indispensable to theoretical endeavour" and he goes on to demand that "the unified theory shall display the highest universality, immediacy, and elegance, in addition to the power of prediction which distinguishes scientific from philosophic theory." To reach his unified theory he begins with Bertrand Russell's conclusion that "it is only structure which we can validly infer from perceptions, and structure is what can be expressed by mathematical logic, which includes mathematics," and he goes on to point out that "science is interested in causal or space-time structure." Then, in an interesting discussion in which he describes the principle of causality as "a rule for selecting isolable processes," he concludes : "The principle of causality requires that those processes alone are isolable in which there is no appearance of new arbitrary features, i.e. of features which cannot be traced to earlier causes within the process." This conception of causality is made more specific by what he calls the *principle of symmetry* : "the symmetry of causes must be repeated in their effects, and any symmetry of effects must therefore be present in their causes . . . new asymmetries cannot arise in an isolable process." But, he adds, though "In isolable processes new distinctions cannot arise . . . earlier distinctions can disappear," as, for example, "We can predict that hot and cold fluids when mixed will reach a uniform temperature, but from this end-result we cannot infer the original difference in temperature." This fact leads him to his Unitary Principle : "Asymmetry tends to disappear, and this tendency is realised in isolable processes."

Mr. Whyte's principles involve certain difficulties. First, at the risk of excessive purism, it may be doubted whether there are grounds for believing that it is *nature* that is simple and in which order is *discovered.* There is in fact no means of judging whether "nature" is simple or complicated (whatever it would mean to make such a judgment). The choice of the simplest of the available hypotheses is purely a matter of convenience. The other main criterion, besides that of economy, by which hypotheses are selected is their range, the limits of which are determined by deduction and experiment leading to verification or falsification. But, since we have no means of

exhausting all the possible alternative theories from which the same facts could be deduced, we can never conclude that any particular theory which as yet remains un-falsified expresses the truth about " nature." Indeed, we need not consider " nature " at all and the principal danger lurking behind convictions about " nature " is that, apart from being irrelevant, they tend to introduce into a particularly successful theory a suggestion of finality that may at a later stage obstruct research.

Moreover, it is very difficult to see exactly what Mr. Whyte's principle of causality tells us and what exactly we are to do with it. Like Newton's conception of force it appears to be based on a tautology, but unlike Newton's definition it can hardly be said that its heuristic value has been demonstrated.

It would be unjust as well as mistaken to dismiss at this stage an explicitly preliminary attempt to produce a " unified science." Mr. Whyte certainly makes most adroit use of his unitary principle to fulfil his demand for universality, that " All processes are to be represented as variants of one universal process," though at times the application is so facile that one may begin to doubt the scientific value of the principle. But biologists in particular may well get some useful ideas from Mr. Whyte's theory of organism. From a few primitive axioms he deduces conclusions which are as suggestive as the methods of reaching them are ingenious. There is no index.

<div style="text-align: right">A. C. CROMBIE.</div>

Wirkungsquantum und Naturbeschreibung. By F. HUND. Deutsche Akademie der Wissenschaften zu Berlin, Vorträge und Schriften, Heft 35. [Pp. 18.] (Berlin: Akademie Verlag, 1949. DM.2.50.)

IN an oration in memory of Max Planck, the author, a theorist who has successfully applied quantum mechanics to various problems of spectroscopy and chemistry, deals with the philosophical implications of the quantum theory. Writers on this subject frequently assert that the quantum theory imposes insuperable limits to the progress of scientific knowledge. Tl e author maintains that the old and the new physics differ essentially only with regard to their specification of objective reality. Previously the smell and taste of a substance were considered as partly due to the action of an observer, whereas the positions of its molecules were regarded as objectively real. In quantum physics the positions of the molecules are, with respect to their dependence on the action of an observer, no better than smell and taste, whereas reality can be specified in terms of abstract mathematical constructs only. In order to establish the quantum theory it was necessary to reconsider the meaning of standardised theoretical notions ; logical standards had to be improved in order to resolve apparent contradictions. All this should be helpful for creating a scientific attitude in the consciousness of mankind.

<div style="text-align: right">R. EISENSCHITZ.</div>

The Story of Atomic Energy. By FREDERICK SODDY, F.R.S. [Pp. viii + 136, with 92 figures.] (London: Nova Atlantis, 1949. 20s. net.)

GREAT interest attaches to this book. It gives an account, written for the general reader, " by the sole surviving participator in their origin, of the discoveries and ideas, which in 1945 culminated in the large-scale destructive

release of tomic * energy." The quarto volume collects 13 fortnightly articles that appeared in *Engineering* during 1947–48. The treatment is broad, starting from Alchemy and the origins of the Atomic Theory and arriving at nuclear fission in Chapter XII. The last chapter discusses the implications of large-scale fission and the social responsibilities of the scientist. Recent developments are therefore seen in a wide perspective, and this indeed is the book's great merit ; but occasionally the reader is taken rather far afield—for instance, on p. 79 into a discussion of the bonding in Werner's co-ordination complexes. Very properly emphasis is laid on the fact that atomic energy was first discovered about 1903.

There are subjects upon which the author has strong personal views, and these produce some hard judgments : on Aristotle and John Dalton, for example, or on quantum mechanics and banking. ("The ordinary man to-day . . . has still to recognise (Alchemy) in its modern disguise as so-called ' banking.' ") Criticism may be made of a few points of detail. The book is intended for the lay reader, and most of it is written simply. But not all ; and some of the difficult passages can be attributed to the use of very long and involved sentences. Again, after reading pp. 79–80, one will be left with the impression that ortho- and para-hydrogen owe their difference to *electronic* spin. Or again the historian may not think that any scientific hypothesis which has enjoyed a period of usefulness ought subsequently to be dismissed as " fundamentally false " (*e.g.* p. 12) ; and especially may he wonder whether even the discoverer of Isotopy is justified in applying such a phrase (p. 21) to a theory which enabled Mendeléeff to predict the pro- perties of three unknown elements. The quality of the printing is as might be expected in a fortnightly magazine, but is not worthy of the author or his book.

The value of this book arises from what Dr. Soddy is uniquely able to give : in a viewpoint based on his long contact with the subject, and yet detached from the sinister developments since it became bedevilled by the fear of the atomic bomb ; in his reminiscences of the exciting early days of Radioactivity research ; and—whether one agrees with them or not—in the wisdom revealed in certain passages. A review cannot be better concluded than by quoting one of those.

" The six disastrous years of World War . . . now (seem) only to have unloosed among the masses a false optimism that the same effort guided into constructive channels could emancipate the whole world, whereas, in fact, (they) represent so great a disaster as to postpone indefinitely any such possibility . . . Last century, not this, was the time to attempt the millenium."

J. C. SPEAKMAN.

Crucibles : The Story of Chemistry from Ancient Alchemy to Nuclear Fission. By B. JAFFE. Revised edition. [Pp. xiv + 480.] (London : Hutchinson's Scientific and Technical Publications, 1949. 18*s.* net.)

IT requires both courage and audacity to attempt an historical treatment of chemistry from its origins to the present day in a book of fewer than 500 pages. Prof. Jaffe undertook this formidable task by weaving his narrative

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* The adjective " tomic " is suggested by the author so as to avoid the verbal contradiction of such phrases as " *atomic* fission."

around a gallery of outstanding figures in the long cavalcade of historical chemistry. In the first five of the nineteen chapters, alchemy is represented by Trevisan, intro-chemistry by Paracelsus, phlogiston by Becher, and the work that undermined phlogiston by Priestley and Cavendish. Next come naturally Lavoisier, Dalton and Berzelius ; and so the story progresses to the present day, ending with chapters on " The men who harnessed nuclear fission " and " Nuclear energy tomorrow."

The book is written in a lively and entertaining style. It is truly described as the story rather than as a history of chemistry. The author is indefatigable in collecting anecdotes and personal details illustrating the characteristics of his chosen figures, and although he amplifies their scientific backgrounds the effect is at times that of a series of picturesque advertising posters. Historically the work improves considerably as the author progresses, and the last half-dozen chapters, dealing chiefly with sub-atomic chemistry, afford a vividly written and valuable review of this fascinating field of modern science, with its ambivalent vista of attractive and forbidding possibilities. These chapters bring out in a striking way the dominating position occupied by the United States in scientific research at the present day.

The least satisfactory part of the book is the treatment of alchemy, a vast subject incapable of attachment to any single personality ; moreover, the bibliography given at the end of the book is not calculated to lead the enquirer much further into this complex field. Mistakes are regrettably numerous ; among them the following may be noted : Berthollet was not a sceptic of the atomic theory in 1890 (p. 131) ; it is not generally accepted that Pictet and Vogel of Geneva synthesised cane sugar in 1928 (p. 178) ; Perkin's discovery of mauve was not the result of mixing at random the contents of two flasks whilst washing bottles in Hofmann's laboratory (p. 190) ; Basil Valentine did not describe antimony in the year when Columbus was discovering America (p. 205) ; and Agricola's *De Re Metallica* was not published in 1530 (p. 205). It is surprising to find such inaccuracies in a revised edition of this praiseworthy contribution to the humanising of science.

JOHN READ.

A Concise History of Astronomy. By PETER DOIG, F.R.A.S. [Pp. xii + 320.] (London : Chapman & Hall, Ltd., 1950. 21s. net.)

SINCE Berry and Bryant wrote the standard English histories of astronomy, forty years and more of prodigious achievement have revolutionised the science. Now the record has been diligently brought up to date by Mr. Peter Doig, the Editor of the *Journal of the British Astronomical Association*, in this latest book of his. It is intended for the general reader, and the Astronomer Royal has contributed a Foreword.

Beginning with a sketch of the problematic astronomy of the ancient East (which Berry deliberately left out of account), and a rather uncertain chapter on that of the Greeks, the story unfolds through the Middle Ages to Copernicus, Kepler, Galileo, and so to Newton and the eighteenth century. From Herschel onwards, the subject is treated in much greater detail (the dividing line between the first and the second halves of the book falling as late as 1850), and the author's familiarity with the technical literature, and with the celestial phenomena themselves, is increasingly in evidence. The breaking-up of the later chapters into a number of separate sections dealing

with special problems or classes of luminaries, though probably unavoidable, is not altogether satisfying to the reader's historical sense. However, it does not lessen the usefulness of the book as a work of reference, both for past history and for novel developments concerning which little information is as yet generally available.

Besides a number of obvious misprints (*e.g. Pupils* for *Papers* in the first footnote on p. 129), we have noticed a number of slips, mainly in the earlier portion of the book. Pythagoras is not supposed to have held that the Earth revolved round the Sun, and the latter round the Central Fire (p. 28). The "great Geometer" is twice misspelt *Appolonius* (pp. 35 and 313). Horrox observed the transit of Venus with Crabtree, not with Gascoigne (p. 72). Descartes died too early (1650) even to admit "the correctness of only parts of Newton's theories" (p. 88). Halley was Savilian Professor of *Geometry*, not of *Astronomy* (p. 101). The variation of latitude is not solely due to meteorological factors (p. 156). And Lockyer was born in 1836, not in 1823 (p. 186).

<div align="right">A. A.</div>

Science, Servant of Man. A Layman's Primer for the Age of Science. By I. BERNARD COHEN. [Pp. xvi + 362, with 7 plates.] (London : Sigma Books, Ltd., 1949. 15s. net.)

" As a historian of science, I am constantly struck by the fact that the average reader of the eighteenth century had a much better grasp of the full meaning and significance of the science of his day than a similar person has in ours. The English poets of the eighteenth century, for example, were not only familiar with the principles of Newtonian mechanics but . . . they integrated Newtonian ideas into their actual poetic writings, and even constructed æsthetic canons in Newtonian terms. The educated layman of that day—whether poet, philosopher, statesman, merchant or dreamer—was able to learn his science by reading popular books by great masters." These included such writers as Fontenelle, Euler, Voltaire and Henry Pemberton.

Science in the twentieth century is so complicated that no one, not even the scientists themselves, can hope to master even in the most general terms more than one or two of its branches. But Dr. Cohen, a distinguished historian of science working at Harvard, has attempted a new method of presenting science as a unity. In this work he describes a number of case-histories from many different branches of nineteenth- and twentieth-century science with the object of learning " under precisely what conditions important scientific discoveries are made, and in just what way the practical applications of science came about."

Most of Dr. Cohen's " cases " are examples of scientific discoveries that have turned out to be practically useful but, as he rightly points out, useful results " have come about primarily as the by-products of the search for truth in the scientific laboratory." Science is investigating the unknown : no one knows where it will go : the early investigators of electricity, penicillin, plant hormones, genetics, fossils, the constitution of the sun had no idea to what uses their results would be put. Yet Dr. Cohen points out that it is impossible to draw a sharp line between pure and applied science and he emphasises again and again that to understand the conditions of scientific discovery we must keep in mind the *milieux* in which discoveries were made. For instance, Watt's steam engine was made at a time when Black was

beginning to understand latent heat, technicians had acquired a sufficient accuracy in metal-working, and there was a particular economic need. Another illustration of the influence of the " total scientific situation " is the difference in attitudes to penicillin in 1928–29 and 1938–39. This " total situation," as Dr. Cohen points out, is quite as indispensable as the presence of scientists with the necessary intellectual equipment and the curiosity that makes them pay attention to facts, however odd and at variance with expectations based on current ideas.

Dr. Cohen has written a book that is both scholarly, interesting and informative and well designed to give the layman a " sympathetic understanding of the scientific enterprise as a whole."

A. C. CROMBIE.

MISCELLANEOUS

Psychical Physics. By S. W. TROMP. [Pp. xvi + 534, with 150 figures.] (Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1949. 60s. net.)

A SERIES of subtle phenomena, including water divining, exist which in general have not been verified by scientific methods. In this book the author gives an account of such phenomena with comprehensive bibliographic references.

The book falls into two main parts (i) an account of the external and internal fields influencing living organisms, and (ii) a detailed description of dowsing, with some experiments carried out by the author. The summary review of the physiological and geological subjects is thorough and is carefully planned.

Although the author refrains from expressing definite belief in some of the phenomena described in the first part of the book, they are described credulously rather than critically, whereas experiments which have given negative results are discredited. For example, experiments which fail to demonstrate mitogenetic radiation are rejected on the grounds that statistical investigation of such phenomena is not permissible because some of the controlling factors are either unknown or ignored. Again, the experimental conclusion of Doelman and Trip that electrostatic fields have no effect on tar carcinoma is rejected as " hasty and typical of the attitude of a great number of scientists if extremely subtle and rather unusual phenomena are reported."

The author believes that a core of truth is hidden within the mass of admittedly spurious data about dowsing. His own experimental results using the electrocardiograph are interpreted in terms of receptors in the human body. No physical receptors sensitive to minute changes in magnetic field strength are known. The skin potential changes measured probably result from variation in sweat secretion arising from suggestion reaching the subject through some other sensory channel.

The author suggests that a systematic exploration of these phenomena in a laboratory of Psychical Physics would enable us to solve " the most fundamental philosophical problems of life."

This book contains much interesting information, but must be read critically.

B. C. A.

Science News 14. Edited by J. L. CRAMMER. [Pp. 160, with 16 plates and 17 figures.] (Harmondsworth : Penguin Books, Ltd., 1949. 1s. 6d. net.)

IN this issue of *Science News* three short articles on Bacteriophage * form most interesting reading, coming as they do from names so closely associated with the subject. The first by Dr. F. W. Twort is largely biographical, in which the author enlarges on his views concerning bacteria as examples of life in a most primitive form, describes his original observations on the effect of a " bacteriolytic agent " on the growth of micrococci obtained from vaccine lymph, and discusses the virus-host relationship and its significance in infectious processes.

Dr. F. D'Herelle gives an historical review of his systematic researches into Bacteriophage, starting with investigations on an infectious disease of locusts caused by a cocco-bacillus, when he noticed " clear spots " occurring in the growth on agar of this micro-organism. The ensuing description of investigations into the properties of Bacteriophage and its application to cholera-infected well water in India are written in a pleasant style and form absorbing reading.

The final article by Dr. Wyckoff gives a scientific description of the properties of Bacteriophage ; the size and shape of coli phage and chemical composition of phage are given. Studies in the genetic structure of phage and the effect of mutation on phage lysis and the properties required to initiate adsorption are described. The process of adsorption and lysis is then dealt with and reference made to the six excellent shadow ultra-micrographs supplied with the article.

There are other informative articles on the Origin of the Solar System (by the Astronomer Royal), Molecular Architecture in Plants, Synthetic Fibres, Viruses and the Veterinary Surgeon, the Electrical Activity of the Human Brain, Television and the Calendar.

W. D. LINSELL.

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*." The Discovery of Bacteriophage," by F. W. Twort, F.R.S. ; " The Bacteriophage," by Felix D'Herelle ; " The Nature of Bacteriophage," by Ralph G. Wyckoff.

BOOKS RECEIVED

Progressive Mathematics. By P. Clyne, A.C.G.I., A.M.I.E.E., Responsible Lecturer in Mathematics in Engineering Dept. at Mid-Essex Technical College, Chelmsford. London : Chapman & Hall, Ltd., 1950. (Pp. xii + 270, with 121 figures.) 15s. net.

Nonlinear Vibrations in Mechanical and Electrical Systems. By J. J. Stoker, Institute for Mathematics and Mechanics, New York University. Pure and Applied Mathematics, Vol. II. New York and London : Interscience Publishers, Inc., 1950. (Pp. xx + 273, with 89 figures.) 40s. net.

Éléments de Calcul tensoriel. By A. Lichnerowicz, Professeur à la Faculté des Sciences de l'Université de Paris. Collection Armand Colin No. 259. Paris : Librairie Armand Colin, 1950. (Pp. 216.). Frs.180.-.

Probability and the Weighing of Evidence. By I. J. Good, M.A., Ph.D., former Lecturer in Mathematics at the University of Manchester. London : Charles Griffin & Co., Ltd., 1950. (Pp. viii + 119.) 16s. net.

Giant Brains or Machines that Think. By Edmund Callis Berkeley, Consultant in Modern Technology. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. xvi + 270, with 77 figures and 17 tables.) 32s. net.

Neue Theorie und Methode der Ephemeridenrechnung. By Karl Stumpff. *Abhandlungen der deutschen Akademie der Wissenschaften zu Berlin, Math.-naturwiss. Klasse*, 1947, No. 1. Berlin : Akademie-Verlag, 1949. (Pp. 88, with 12 figures.) DM.15.-.

Between Earth and Sky. By Auguste Piccard. Translated from the French by Claude Apcher. London : The Falcon Press, 1950. (Pp. 157, with 60 plates and 13 diagrams.) 15s. net.

Radiative Transfer. By S. Chandrasekhar, F.R.S., Professor of Theoretical Astrophysics, University of Chicago. The International Series of Monographs on Physics. Oxford : at the Clarendon Press, 1950. (Pp. xiv + 393, with 35 figures and 35 tables.) 35s. net.

The Climates of Addu Atoll, Agalega Islands and Tristan da Cunha. By E. V. Newnham, B.Sc. Meteorological Office Professional Notes No. 101. London : H.M. Stationery Office, 1949. (Pp. 20, with 4 plates, 5 figures and 22 tables.) 6d. net.

The Meaning of Relativity. By Albert Einstein. Fourth edition. London : Methuen & Co., Ltd., 1950. (Pp. vi + 145.) 7s. 6d. net.

A Textbook of Physics. Vol. I : Mechanics and Properties of Matter. By R. C. Brown, B.Sc., Ph.D., Senior Lecturer in Physics, University College, London. London, New York, Toronto : Longmans, Green & Co., 1950. (Pp. x + 276 + ix, with 259 figures.) 10s. 6d.

Physics. By C. L. Boltz, B.Sc. Harrap's Torch Books. London : George G. Harrap & Co., Ltd., 1950. (Pp. 384, with frontispiece and 115 figures.) 10s. 6d. net.

The Physics of High Pressure. By P. W. Bridgman, Ph.D., D.Sc., For. Mem. R.S., Nobel Laureate, Hollis Professor of Mathematics and Natural Philosophy at Harvard University. New impression, with supplement. London : G. Bell & Sons, Ltd., 1949. (Pp. viii + 445, with 93 figures, including 3 plates, and 25 tables.) 35s. net.

Stereoscopic Photography. Its Application to Science, Industry and Education. By Arthur W. Judge, A.R.C.S., D.I.C., Wh.Sc. Third edition. London : Chapman & Hall, Ltd., 1950. (Pp. 480, with frontispiece, 21 plates and 319 figures.) 42s. net.

Theory of Hearing. By Ernest Glen Wever, Professor of Psychology, Princeton University. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall. Ltd., 1949. (Pp. xiv + 484, with frontispiece, 137 figures and 8 tables.) 48s. net.

Acoustic Measurements. By Leo L. Beranek, S.D., D.Sc. (Hon.), Associate Professor of Communication Engineering and Technical Director of the Acoustics Laboratory, Massachusetts Institute of Technology. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. viii + 914, with 519 figures and 43 tables.) 56s. net.

Physical Properties of Glass. By J. E. Stanworth, Research Laboratory, British Thomson–Houston Co., Ltd., Rugby. Monographs on the Physics and Chemistry of Materials. Oxford : at the Clarendon Press, 1950. (Pp. viii + 224, with 107 figures and 39 tables.) 21s. net.

Photons and Electrons. By K. H. Spring, M.Sc. Methuen's Monographs on Physical Subjects. London : Methuen & Co., Ltd. ; New York : John Wiley & Sons, Inc., 1950. (Pp. viii + 108, with 38 figures and 8 tables.) 7s. 6d. net.

Cosmical Electrodynamics. By H. Alfvén, Professor of Electronics, Royal Institute of Technology, Stockholm. The International Series of Monographs on Physics. Oxford : at the Clarendon Press, 1950. (Pp. viii + 237, with 78 figures and 8 tables.). 25s. net.

Advances in Electronics. Vol. II. Edited by L. Marton, National Bureau of Standards, Washington, D.C. New York : Academic Press, Inc., 1950. (Pp. x + 378, with 162 figures and 15 tables.) $7.60.

Counting Tubes : Theory and Applications. By S. C. Curran, Ph.D., F.R.S.E., and J. D. Craggs, M.Sc., Ph.D. Laboratory Technique Monograph. London : Butterworths Scientific Publications, 1949. (Pp. xii + 238, with 119 figures and 23 tables.) 35s. net.

An Introduction to the Theory and Design of Electric Wave Filters. By F. Scowen, B.Sc., A.Inst.P., Post Office Research Station. With a Foreword by Sir Archibald J. Gill. Second edition. London : Chapman & Hall, Ltd., 1950. (Pp. xii + 188, with 71 figures.) 18s. net.

Aerials for Centimetre Wave-Lengths. By D. W. Fry and F. K. Goward. Modern Radio Technique Series. Cambridge : at the University Press, 1950. (Pp. x + 172, with 65 figures.) 18s. net.

Electric Power System Control. By H. P. Young, M.I.E.E., M.A.I.E.E., Senior Lecturer in Electrical Engineering, The Polytechnic, London. Third edition. Monographs on Electrical Engineering, Vol. XI. London : Chapman & Hall, Ltd., 1950. (Pp. xvi + 456, with frontispiece and 319 figures, including 27 plates.) 28s. net.

Transformation Calculus and Electrical Transients. By Stanford Goldman, Ph.D., Professor of Electrical Engineering, Syracuse University. Prentice-Hall Electrical Engineering Series. New York : Prentice-Hall, Inc. ; London : Constable & Co., Ltd., 1949. (Pp. xiv + 439, with 185 figures.) 30s. net.

Heat Transfer. Vol. I. By Max Jakob, Research Professor of Mechanical Engineering, Illinois Institute of Technology. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. xxx + 758, with 251 figures and 91 tables.) 96s. net.

The Chemical Elements and their Compounds. Vols. I and II. By N. V. Sidgwick, Fellow of Lincoln College, Hon. Student of Christ Church, formerly Professor of Chemistry in the University of Oxford. Oxford : at the Clarendon Press, 1950. (Pp. xxxviii + 1703.) 70s. net the set.

Boron Trifluoride and Its Derivatives. By Harold Simmons Booth, Hurlbut Professor of Chemistry, Western Reserve University, and Donald Ray Martin, Assistant Professor of Chemistry, University of Illinois. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. x + 315, with 40 figures and 41 tables.) 4Cs. net.

Advances in Catalysis and Related Subjects. Vol. II. Edited by W. G. Frankenburg, Lancaster, Pa., V. I. Komarewsky, Chicago, Ill., and E. K. Rideal, London, England. New York : Academic Press, Inc., 1950. (Pp. xii + 292, with 41 figures and 25 tables.) $6.80.

Frontiers in Colloid Chemistry. Edited by R. E. Burk, Plastics Department, E. I. du Pont de Nemours & Co., and Oliver Grummitt, Morley Chemical Laboratory, Western Reserve University. Frontiers in Chemistry, Vol. VIII. New York and London : Interscience Publishers, Inc., 1950. (Pp. x + 157, with 54 figures and 9 tables.) 32s. net.

Organic Chemistry. By Paul Karrer, Professor at the University of Zürich. Original translation by A. J. Mee, M.A., B.Sc. Fourth English edition revised and enlarged in accordance with the eleventh German edition by H. V. Simon, D.Phil., and N. G. Bisset, B.Sc., A.R.C.S. Amsterdam : Elsevier Publishing Co., Inc. ; London : Cleaver-Hume Press, Ltd., 1950. (Pp. xxiv + 983.) 57s. 6d. net.

Organic Reactions, Vol. V. Roger Adams, Editor-in-Chief. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. (Pp. viii + 446, with numerous tables.) 48s. net.

Technique of Organic Chemistry. Vol. III : Heating and Cooling ; Mixing ; Centrifuging ; Extraction and Distribution ; Dialysis and Electrodialysis ; Crystallization and Recrystallization ; Filtration ; Solvent Removal, Evaporation, and Drying. Edited by Arnold Weissberger. New York and London : Interscience Publishers, Inc., 1950. (Pp. x + 661, with 324 figures and 42 tables.) 80s. net.

Synthetische Methoden der Organischen Chemie. Repertorium 3. By W. Theilheimer. Basel : S. Karger, 1949. (Pp. viii + 412.) Swiss Frs. 40.-.

An Introduction to Practical Organic Chemistry. By R. V. V. Nicholls, Associate Professor of Chemistry, McGill University. Second edition. Toronto and London : Sir Isaac Pitman & Sons, Ltd. (Pp. x + 226, with 21 figures and 3 tables.) 15s. net.

The Alkaloids. Chemistry and Physiology. Vol. I. Edited by R. H. F. Manske, Dominion Rubber Research Laboratory, Guelph, Ontario, and H. L. Holmes, University of British Columbia, Vancouver. New York : Academic Press, Inc., 1950. (Pp. viii + 525, with 17 figures, 15 charts and 38 tables.) $10.00.

Advances in Protein Chemistry. Vol. V. Edited by M. L. Anson, Continental Foods, Inc., Hoboken, N.J., and John T. Edsall, Harvard Medical School, Boston, Mass. Associate Editor for the British Isles, Kenneth Bailey, Trinity College, Cambridge. New York : Academic Press, Inc., 1949. (Pp. x + 481, with 35 figures and 80 tables.) $7.50.

Structural Carbohydrate Chemistry. By E. G. V. Percival, D.Sc., Ph.D., F.R.I.C., Reader in Chemistry, University of Edinburgh. London : Frederick Muller, Ltd., 1950. (Pp. viii + 246.) 25s. net.

The Art and Science of Brewing. By C. A. Kloss, B.Sc., A.R.I.C., Chief Chemist, Mortlake Brewery, Watney Combe Reid & Co., Ltd. London : Stuart and Richards, 1949. (Pp. x + 121, with 8 plates and 9 figures.) 12s. 6d. net.

Physical Methods in Chemical Analysis. Vol. I. Edited by Walter G. Berl, Applied Physics Laboratory, Johns Hopkins University, Silver Spring, Maryland. New York : Academic Press, Inc., 1950. (Pp. xiv + 664, with 206 figures and 63 tables.) $12.00.

Advanced Chemical Calculations. By Sylvanus J. Smith, M.A., late Senior Scholar of Trinity College, Cambridge, Chemistry Master, The High School, Newcastle, Staffs. London : Macmillan & Co., Ltd., 1950. (Pp. viii + 454, with 38 figures.) 17s. net.

Metal Finishing Handbook. By P. A. Cartwright, A.M.G.I., M.I.E.I., L.I.M., Major, the Royal Army Ordnance Corps. London and Glasgow : Blackie & Son, Ltd., 1950. (Pp. xii + 216, with frontispiece and 32 figures.) 15s. net.

Géologie de l'Afrique. By Raymond Furon, Sous-directeur au Muséum National d'Histoire Naturelle, Professeur de Géologie coloniale (O.R.S.O.M.). Paris : Payot, 1950. (Pp. 350, with 34 figures.) Frs. 1380.–.

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SCIENCE PROGRESS

THE TRANSURANICS AND OTHER NEWLY DISCOVERED ELEMENTS

By H. J. EMELÉUS, M.A., D.Sc., F.R.S.

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DURING the last fifteen years no fewer than nine new elements have been discovered, while a tenth, francium, has been examined chemically for the first time. Four of these elements, technetium ($Z = 43$), prometheum ($Z = 61$), astatine ($Z = 85$) and francium ($Z = 87$) correspond with the gaps which previously existed in the periodic table, while the remaining six, neptunium ($Z = 93$), plutonium ($Z = 94$), americium ($Z = 95$), curium ($Z = 96$), berkelium ($Z = 97$) and californium ($Z = 98$) are transuranic elements.[*]

In reviewing the production and chemistry of these elements it will be convenient to consider the transuranics first. Their discovery originated in Fermi's observation that slow neutrons are readily captured by atomic nuclei, the resulting nucleus being in most cases β-active and giving, therefore, as its decay product an element of atomic number one greater than that of the parent element. The slow neutron bombardment of uranium was found to result in two distinct processes. The isotope U^{235} underwent fission into lighter nuclei and neutrons, while the heavier isotope, U^{238}, was able to capture neutrons, forming the nucleus U^{239} which, by β-decay, gave the neptunium isotope Np^{239}. Both of these processes occurring in uranium led to the discovery of new elements, for among the fission products of uranium are radioactive isotopes of technetium and prometheum. Quite apart from neutron capture by uranium and fission, however, the cyclotron has also proved an invaluable tool in the development of this new field.

[*] References to original papers are not given in the text, but summaries of work on the transuranics are available in a recent article by M. W. Lister (*Quart. Rev. Chem. Soc.*, 1950, **4**, 20) and in two volumes of the National Nuclear Energy Series by G. T. Seaborg, J. J. Katz and W. M. Manning (N.N.E.S., Division IV, Vol. 14B, McGraw-Hill Book Co. Inc., New York, 1949).

The uranium isotope U^{239} produced in the neutron irradiation of U^{238} decays according to the scheme shown below (1), forming successively Np^{239}, Pu^{239} and U^{235}.

$$U^{239} \xrightarrow[\text{23 mins.}]{\beta} Np^{239} \xrightarrow[\text{2 3 d.}]{\beta} Pu^{239} \xrightarrow[\text{2·1} \times 10^4 \text{ y.}]{\alpha} U^{235} \longrightarrow \qquad . \quad (1)$$

$$U^{238}(d,2n) \longrightarrow Np^{238} \xrightarrow[\text{2 0 d.}]{\beta} Pu^{238} \xrightarrow[\text{50 y.}]{\alpha} U^{234} \longrightarrow \qquad . \qquad (2)$$

$$U^{238}(n,2n) \longrightarrow U^{237} \xrightarrow[\text{8 0 d.}]{\beta} Np^{237} \xrightarrow[\text{2} \times 10^6 \text{ y.}]{\alpha} Pa^{233} \longrightarrow \qquad . \quad (3)$$
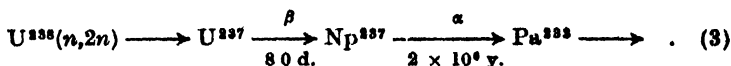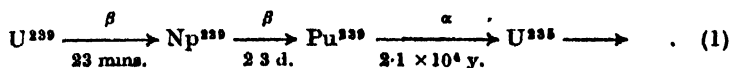
This is, however, only one of several ways in which isotopes of neptunium and plutonium may be produced. The reaction (2) above, for example, is based on the bombardment of uranium with deuterons in the cyclotron and is the method by which Seaborg and his co-workers produced plutonium in 1940. With the material so obtained they studied plutonium chemistry on a tracer scale and were able to provide information for later technological developments. The third set of reactions (3) occurs with fast neutrons from the cyclotron or the pile and is of particular interest because it yields a neptunium isotope of half-life less by a factor of only about 10^3 than that of uranium itself, which is particularly convenient for chemical studies.

Americium and curium also form a number of radioactive isotopes which may be produced, as shown below, either in the cyclotron (4, 5) or in the pile (6). The isotope Am^{241} is formed by the cyclotron bombardment of U^{238} with α-particles (4). In the second case the plutonium isotope Pu^{239}, which is available in quantity from the pile, is used as the cyclotron target. The third set of reactions shows a process which can go on when plutonium is subjected to slow neutron bombardment. It is also possible to start with the americium isotope Am^{241} prepared according to (1) and subject it to neutron bombardment.

The discovery of the two remaining transuranic elements has been announced only very recently. Both have been obtained by Seaborg and his co-workers, the first, berkelium, by bombarding the americium isotope Am^{241} with helium ions in the cyclotron. The isotope formed is believed to be Bk^{243} and it decays with a 4·8 hour half-life by electron capture with approximately 1 per cent. α-decay branching. Element 98, to which the name californium has been given, is formed by bombarding Cm^{242} with helium ions. It is an α-active isotope of half-life 45 minutes. Both are formed in an (α, $2n$) reaction. No information on the chemistry of these elements is yet available, though they were separated from the cyclotron

target material by using the ion exchange method which is referred to later.

A number of other isotopes of the first four transuranic elements are known in addition to those mentioned. One of the most

$$U^{238}(\alpha,n) \longrightarrow Pu^{241} \xrightarrow[1\ y.]{\beta} Am^{241} \xrightarrow[500\ y.]{\alpha} Np^{237} \longrightarrow . \qquad . \quad (4)$$

$$Pu^{239}(\alpha,n) \longrightarrow Cm^{242} \xrightarrow[5\ months]{\alpha} Pu^{238} \xrightarrow{\alpha} . \qquad . \quad . \quad (5)$$

$$Pu^{239}(n,\gamma) \longrightarrow Pu^{240} \xrightarrow[6000\ y.]{\alpha} U^{236} \longrightarrow$$
$$\downarrow n,\gamma$$
$$Pu^{241} \xrightarrow[1\ y.]{\beta} Am^{241} \xrightarrow[500\ y.]{\alpha} . \qquad\qquad\qquad (6)$$
$$\downarrow n,\gamma$$
$$Am^{242} \xrightarrow[18\ h.]{\beta} Cm^{242} \xrightarrow[5\ months]{\alpha} Pu^{238}$$
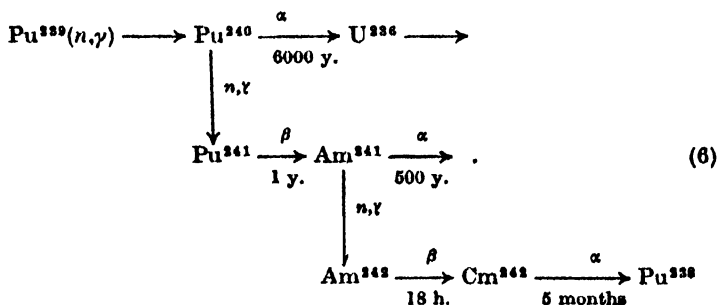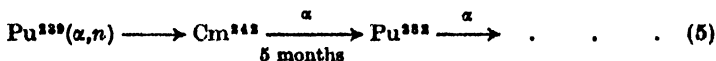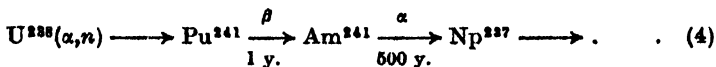
interesting aspects of their discovery is that, although some connect with and extend the three classical decay series, others are members of the missing fourth series, the so-called $(4n + 1)$ series which is not found in nature.

THE ELECTRONIC CONFIGURATION OF THE TRANSURANIC ELEMENTS

There was, prior to the discovery of the transuranic elements, considerable speculation as to the way in which the electrons in uranium and the elements immediately preceding it were grouped in the available electron shells. Two possibilities existed for the elements beyond actinium, which appeared to have a single valency of three and was therefore considered as an analogue of lanthanum. In the succeeding elements, thorium, protoactinium and uranium, either the 5f or the 6d orbits could be filled. The first arrangement would mean that these elements formed part of a new series analogous to the rare earths, while the second would lead to a new series of transition elements, some members of which would resemble the platinum metals. The discovery of the transuranics has brought this issue to the fore. The evidence available shows that there is only a small difference in energy between the 5f and 6d orbits. In thorium and possibly also protoactinium the latter are filled

preferentially, whereas in uranium and the elements which follow it is clear that the $5f$ shell is occupied.

The physical evidence bearing on this point is very incomplete, but the atomic spectra of thorium and uranium have been studied and the former is found to have the four valency electrons in $6d^27s^2$. Uranium on the other hand has the six valency electrons in $5f^36d^17s^2$.* Since uranium has electrons in the $5f$ shell there is a strong presumption that in the following elements this shell will be further developed. Additional support for this viewpoint is provided by the absorption spectra of compounds of uranium and the transuranics. It is known that the tervalent rare earth ions owe their colour to transitions in the $4f$ levels and that, because of the deep-seated nature of these levels, particularly sharp absorption bands result. Observations with aqueous solutions containing ions of the transuranics show a type of absorption very similar to that found for the rare earths. Even more striking are the results obtained with solid ionic crystals. Solid americium trichloride, for example, gives very sharp absorption bands which are from 1 to 5 A. wide.

Magnetic susceptibility measurements also support the hypothesis that the $5f$ shell is in process of being filled in the transuranics. Unfortunately the exact paramagnetism to be expected on the basis of either $5f$ or $6d$ electrons cannot be readily predicted. There is, however, a general similarity between observed values and those for rare earth ions with a corresponding number of electrons above the rare gas core. The following values are quoted by Lister (*loc. cit.*) :

Ion.	No. of Electrons above Rn Core.	Moment	Ion.	No of Electrons above Rn Core.	Moment.
NpO_2^{2+} . .	1	2·40	U^{3+} . . .	3	3·20
NpO_2^+ .	2	2·96	Np^{4+} . .	3	3·03
PuO_2^{2+} . .	2	2·95	Pu^{4+}. . .	4	1·85
U^{4+} . . .	2	2·91	Pu^{3+}. . .	5	0·90
			Am^{3+} . .	6	·0·8

Further support for the rare earth analogy comes from measurements of the ior radii. The structures of a surprisingly large number of crys e compounds of uranium, neptunium, plutonium and americium ha now been determined and it is possible to assign

* This terminol is used to describe the distribution of electrons, their main shells bei numbered from 1 to 7 with increasing distance from the nucleus. In main shell there are subsidiary groups of electrons (s, p, d, f). The tion $5f^36d^17s^2$ thus means that there are 3 electrons in the f group of the shell, one in the d group of the sixth shell, and two in the s group of the th or outermost shell.

definite radii to the ions. The following data, quoted by Lister
(*loc. cit.*), are based on measurements made on trifluorides, trichlorides,
tribromides and dioxides :

Element.	Ac	Th	Pa	U	Np	Pu	Am
Radius of tervalent ion in A	1·11	—	—	1·04	1·02	1·01	1·00

Rare Earth.	La	Ce	Pr	Nd	—	Sm	Eu
Radius of tervalent ion in A	1·04	1·02	1·00	0·99	—	0·98	0·97

The contraction in radius for the rare earth ions with increasing
atomic number, which is known as the lanthanide contraction, is
due to an increase in the effective nuclear charge (*i.e.* the nuclear
charge minus the screening effect of the other electrons) with atomic
number. This arises from the fact that the screening effect of the
extra electrons in the 4*f* shell does not compensate for the increased
nuclear charge as the series is ascended. As a result the outer
electrons, the position of which determines the ion size, are drawn
closer to the nucleus and the ions become progressively smaller until
the 4*f* shell is completed. It is probable that the same cause is
responsible for the steady decrease in the size of the transuranic
ions, though a similar contraction in ion size would accompany the
filling of the 6*d* orbitals.

The chemical evidence for the rare earth analogy is at first sight
far less convincing. Uranium, for example, is most stable in the
sexavalent state, whereas, if there were a complete analogy with
the lanthanides, it and the transuranics would be predominantly
trivalent. The 5*f* electrons are, however, further from the nucleus
than are those in the 4*f* shell of the rare earths and are therefore
more likely to be removed by oxidation. On this basis, it is not
surprising that higher valencies appear. The lower valency states
of the transuranics become more stable as the series is ascended and
curium resembles gadolinium closely in having a unique valency of
three. There is also a striking point of similarity between americium
and europium in that both have a valency of two. These points
are discussed in greater detail in the following section.

The Chemistry of the Transuranics

The chemistry of these elements, and that of plutonium in
particular, has been extensively studied during the last decade.
Initially the quantities used were extremely small and tracer
techniques were largely employed. As the work developed, however,

visible and weighable amounts became available and normal micro-chemical methods were applied. The hazards arising from the radio-active character of the transuranics have limited most of the chemical studies to this scale of operation.

The transuranics behave chemically as if they were part of a second rare earth group, rather than of a new group of transition elements analogous to the platinum metals. As has been pointed out already, this does not imply a principal valency of three through-out the group and, in fact, both neptunium and plutonium have valencies ranging from three to six which parallel those of uranium. Curium, however, has, as far as is known at present, a single valency of three, but americium has valencies of two, three and almost certainly also of five and six.

The ions known to be formed in solution are shown below :

$$UO_2^{2+} \qquad NpO_2^{2+} \qquad PuO_2^{2+} \qquad AmO_2^{2+}$$
$$UO_2^{+} \qquad NpO_2^{+} \qquad PuO_2^{+}$$
$$U^{4+} \qquad Np^{4+} \qquad Pu^{4+}$$
$$U^{3+} \qquad Np^{3+} \qquad Pu^{3+} \qquad Am^{3+}$$
$$\qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad Am^{2+}$$

In the case of uranium the uranyl ion, UO_2^{2+}, represents the most stable state. Moderately strong reducing agents convert it to the U(IV) and U(III) states and there is good physicochemical evidence that the ion UO_2^{+} also exists in solution, though it readily dispropor-tionates.* Neptunium gives an analogous series of ions, but sexi-valent neptunium is more difficult to prepare than the corresponding state for uranium while the quinquevalent state is more stable in aqueous solution. Plutonium forms analogous ions but the drift in their relative stabilities results in Pu(IV) being the most stable state. It is very readily formed from Pu(VI) and is also reduced to Pu(III) by reagents such as sulphur dioxide or the iodide ion. The relative stabilities of these states is shown by the following table of potentials relative to the normal hydrogen electrode, in which the smaller negative potential indicates that the oxidised state of the couple is more stable (Lister, *loc. cit.*). The values quoted are for M-hydro-chloric acid solutions :

Couple.	U	Np	Pu
III/IV	+ 0·63	− 0·14	− 0·97
IV/V	− 0·55	− 0·74	− 1·13
V/VI	− 0·06	− 1·14	− 0·91

* Disproportionation is a term used to describe the change of a compound in a single valency state into two compounds, one with a higher and one with a lower valency state.

Curium is not known to form ions analogous to those of the higher valency states of uranium, neptunium and plutonium. Americium, on the other hand, may be reduced to a bivalent state, or oxidised to Am(V) or Am(VI). In the sexavalent state it is probably present as the americyl ion, AmO_2^{++}, since it forms with sodium acetate a compound $NaAmO_2Ac_3$, which is isomorphous with the corresponding uranium and plutonium derivatives.

Many compounds of the transuranics have now been prepared both by ionic and by dry reactions. Metallic neptunium, plutonium and americium are obtained by reduction of the fluorides with barium vapour. The fact that so vigorous a reducing agent is necessary emphasises the basic character of these metals and their essential difference from the platinum metals. Various oxides are also known, as is shown by the formulæ tabulated below, though it is likely that others remain to be discovered.

UO	NpO	PuO	AmO	
		Pu_2O_3		(Cm_2O_3)
		Pu_4O_7		
UO_2	NpO_2	PuO_2	AmO_2	
U_3O_8	Np_3O_8			
UO_3				

Orthodox methods have been used, in the main, for the preparation of these compounds, though much of the work has been done on a very small scale. Many have been examined by X-ray methods for the determination of their structures. Thus the monoxides UO, NpO, PuO and AmO are known to have a crystal structure of the sodium chloride type, while the dioxides UO_2, NpO_2, PuO_2, AmO_2 and also ThO_2 have a fluorite structure. Similar structural studies have been made on many other groups of compounds (e.g. the halides, nitrides and carbides) and this work, much of which has been done by W. H. Zachariasen and his co-workers, has been of immense value in opening up the new field. The methods of X-ray analysis have proved to be readily applicable to the examination of small quantities, the only major complication being the blackening of the photographic plate by strongly radioactive specimens during their study.

Hydroxides of the lower valency states are readily precipitated from solution, the trihydroxides of neptunium and plutonium being readily oxidised. Americium hydroxide, however, is a stable pink gelatinous substance. In the sexavalent state plutonium resembles uranium in that it shows acidic properties, plutonates and polyplutonates being readily formed. This behaviour is also observed with neptunium though not with americium and curium. Plutonium

differs from uranium, however, in that solutions containing the plutonyl ion are reduced by hydrogen peroxide with precipitation of peroxy complexes of quadrivalent plutonium which are probably analogous to those of thorium. Uranium under similar conditions forms hydrated UO_4, which is a U(VI) derivative. Several sulphides of neptunium and plutonium (Np_2S_3, NpOS, Pu_2S_3 and Pu_2O_2S) have been prepared by dry reactions, such as that between an oxide and hydrogen sulphide. All are derived from valency states of four or less, the trisulphides being isomorphous with U_2S_3.

The general parallel between uranium, neptunium and plutonium may be further illustrated by the halides and oxyhalides. Thus hexafluorides of uranium and neptunium may be prepared by direct fluorination of the tetrafluorides and are very similar. The existence of plutonium hexafluoride is, however, not fully established : it is certainly less stable than the neptunium compound. Neptunyl and plutonyl halides of the type MO_2X_2 are known corresponding to the uranyl halides. The tetra- and trifluorides of these two elements, like the uranium compounds, are insoluble and may either be precipitated from aqueous solution or prepared by hydrofluorination of the oxides. Neptunium tetrachloride and tetrabromide are known, but the corresponding plutonium compounds have not been isolated, attempts to prepare them leading normally to the more stable trihalides. In addition to the simple halides, both neptunium and plutonium form a number of complex halides corresponding in some cases to thorium and uranium complexes.

Apart from the halides, many other salts of the neptunyl and plutonyl radicals and of the quadri- and tervalent ions of those elements are known, and in a number of instances are isomorphous with the corresponding uranium compounds. Numerous derivatives of plutonium with organic complexing agents have also been described. Uranium and plutonium metals both combine with hydrogen, the products being interstitial hydrides the formulæ of which approximate to UH_3 and PuH_3. A plutonium nitride, PuN, and a carbide, PuC, have likewise been described and correspond to the uranium compounds UN and UC.

Americium and curium are, on the whole, much less well known and our knowledge of their chemistry is still based largely on the results of tracer studies. It is, however, known that americium may be oxidised to higher oxidation states (probably Am V and Am VI). The trihalides and trisulphide (Am_2S_3) have been prepared and the hydroxide $Am(OH)_3$ when ignited at $1000°$ form the black oxide AmO_2. This, on reduction in hydrogen gives the oxide AmO, which is isomorphous with UO and NpO. The ion Am^{3+} is also

believed to exist, since sodium amalgam reduction of a solution containing Eu^{3+}, Sm^{3+}, Am^{3+} and Cm^{3+} leads to precipitation of insoluble europous sulphates with which americium is coprecipitated. Curium does not follow americium either in this reaction or on oxidation.

The difficulties of working with curium are well illustrated by L. B. Werner and I. Perlman's separation of pure curium compounds from americium. The isotope studied was Cm^{242}, which may be prepared by the neutron irradiation of Am^{241} ($Am^{241}(n, \gamma)Am^{242}$:

$Am^{242} \xrightarrow[\text{18 hr.}]{\beta -} Cm^{242}$). It is an α-emitter with a half-life of 5 months, and gives seven billion disintegrations per minute per microgram of Cm^{242}. As a result of this decay, which amounts to roughly 0·5 per cent. per day, its solutions will always be contaminated with the decay product, plutonium, and there is also considerable radiation hazard.

The problem of separation of curium from the large excess of americium with which it was associated was rather similar to that of separating adjacent rare earths. The most satisfactory method was to use a cation exchange resin (Dowex-50), as has been done recently with rare earth mixtures. The americium and curium were adsorbed from pH 1·5 citrate solution in the top layer of a glass column packed with the ammonium form of the resin. A 0·25 M citrate solution at pH 3·05 was then passed slowly through the column, and because of differences in the ion-exchange equilibrium and the strengths of the citrate complexes, the americium and curium were eluted at different rates, the curium being washed out preferentially. By measuring the activity of successive 2-ml. samples from the column it was possible to obtain a cut containing almost pure curium and another containing almost pure americium. From this curium-containing fraction the trifluoride was precipitated in presence of argentic silver, which served to oxidise the accumulated daughter element, Pu^{238}, to a fluoride-soluble state. With curium solutions obtained in this way it was shown that the trivalent ion showed practically no light absorption in the visible spectrum, but absorbs strongly below 4500 A. This is an interesting point of similarity with the corresponding rare earth gadolinium, the absorption of which is also limited to the ultraviolet.

PROMETHEUM

The search for an element of atomic number 61 in nature has been carried out by various investigators with very great care, but the only evidence for its existence is that neodymium (Z = 60) is

probably β-active. From what has already been said it is clear that synthesis of this element from neodymium by neutron irradiation should be feasible. In fact, several isotopes have now been made, the best known being Pm^{147}, Pm^{148} and Pm^{149}. The production of the prometheum isotope Pm^{147} in the fission of U^{235} occurs with a yield of 2·6 per cent., *i.e.* this isotope is found in 2·6 per cent. of all fission, and very considerable quantities will then be produced in a pile during operation. The same isotope is also produced if neodymium is subjected to neutron irradiation in the pile

$$(Nd^{146}(n, \ \gamma) \rightarrow Nd^{147} \overset{\beta}{\rightarrow} Pm^{147}).$$ The separation of prometheum from other fission products is a difficult operation chemically and also because of the high-level activity encountered if more than tracer amounts are sought. The ion exchange method has been applied with great success. This entails in the first place absorption of all the cations present on a column of the synthetic phenolic exchange resin known as amberlite. The following steps are :

(1) Removal of Ru by washing column with water and dilute H_2SO_4.
(2) Removal of Zr and Nb with 0·5–0·7 per cent. oxalic acid.
(3) Fractional elution of the rare earth fission product (including prometheum) with a citrate solution at a controlled pH.
(4) Removal of caesium from the fractions containing prometheum.

The final separation of prometheum is done by elution from a fresh column, the process being controlled throughout by observing the radioactive characteristics of the material eluted.

Relatively little has as yet been published about prometheum : the most conclusive evidence for the identity comes from the photography of the X-ray emission spectrum, which gives lines in the position predicted by Moseley's Law. Lines in the optical emission spectrum have also been photographed. The chemistry of prometheum even when it is known in detail is unlikely to present points of special interest since it is certain to be that of a normal rare earth. Both the nitrate and the chloride have been described.

TECHNETIUM

The discovery of this element was claimed in 1925 by Noddack, Tacke and Berg, at the same time as they discovered rhenium. It was named masurium. The evidence for its existence in nature is, however, very questionable and the early observations have never been confirmed. The first investigation of artificially radioactive isotopes of technetium was made by Perrier and Segrè in 1937.

They examined a molybdenum target which had been bombarded with deuterons and secondary neutrons in the Berkeley cyclotron. The surface of the target was dissolved in ammoniacal hydrogen peroxide, and molybdenum was removed with 8-hydroxyquinoline. A low energy β-activity was observed which was shown to be separated from the solution with a rhenium carrier, but not with molybdenum, niobium or zirconium, radioactive isotopes of which might have been found in the original bombardment of molybdenum. With the material obtained in this way a number of tracer studies were carried out. Thus it was shown that the technetium could be deposited electrolytically on platinum, the deposit being volatile in air at 300°. It was also precipitated quantitatively with rhenium in 0·4–5 NHCl as sulphide. These observations, however, were made with minute amounts of material and it was not possible to obtain material for macrochemical studies by the use of the cyclotron.

Technetium is one of the relatively abundant fission products of uranium (6 per cent.), and material from this source has enabled some more definite information on the element and its compounds to be obtained. The starting material for the isolation of technetium is uranium taken from the pile and containing a mixture of fission products. This is dissolved in concentrated hydrochloric acid, and uranium tetrachloride is oxidised to uranyl chloride by hydrogen peroxide. Platinum chloride is added and hydrogen sulphide passed at 90°, when platinum sulphide is precipitated with other acid-insoluble sulphides, including that of technetium (Tc_2S_7). After dissolving the sulphide precipitate in ammoniacal hydrogen peroxide and evaporating to dryness with the addition of bromine, the residue is distilled with 18-N sulphuric acid, when technetium distils as the oxide. To obtain the technetium in a state of radio-chemical purity it is recycled several times through sulphide precipitations and sulphuric acid distillations. The isotope of technetium found in fissions is Tc^{99}, which is an emitter of β-rays with a maximum energy of 0·32 M.e.v., and a half-life of $4·7 \times 10^5$ years. The long life and the low energy of the β-particles make this material particularly suitable for chemical studies and there is no doubt that, in time, the general chemistry will become as well known as that of rhenium. At present, however, detailed chemical information is slight. The formation of an insoluble sulphide, Tc_2S_7, is known, as is the formation of pertechnates such as NH_4TcO_4, which are analogous in type to the permanganates and perrhenates. The only evidence at present for the existence of lower valency states of technetium is the fact that it is coprecipitated with manganese dioxide and manganese salts in the presence of strong reducing

agents. It is virtually certain, however, that in time pure compounds of the lower valent state of technetium will be prepared as more material becomes available. The optical and X-ray spectra have been examined and the metal has been prepared by reduction of the heptasulphide in hydrogen at 1000°. It is structurally related to rhenium and ruthenium.

ASTATINE

This element has not been detected in nature : it is the halogen below iodine in the periodic table. A number of well characterised isotopes have, however, been produced artificially. That used in the chemical studies so far reported is the isotope At^{211} which is produced when a bismuth target is bombarded with α-particles of 21–29 M.e.v. energy produced in the cyclotron. It is an α-particle emitter with a half-life of 7·5 hours, and the activity is so high as to preclude chemical studies on anything but a tracer scale. Thus a molar solution of a salt of this isotope would emit $1·54 \times 10^{16}$ α-particles per c.c. per second, and most experiments have been done at concentrations of 10^{-11} to 10^{-15} molar.

The isolation of astatine from the irradiated bismuth target is effected by distilling off the astatine in high vacuum at the melting-point of bismuth, the halogen being collected in a narrow U-tube cooled in liquid nitrogen. It is then dissolved in concentrated nitric acid and diluted with water. The halogen-like character of the astatine has been established by a series of elegant tracer experiments carried out by Johnson, Leinenger and Segrè. Thus it was shown in a series of ionic migration tests that astatine invariably forms an anion, whether its solution be treated with strong oxidising or reducing agents. After reduction with sulphur dioxide or zinc astatine is precipitated with silver or thallous iodides, which is strong evidence that the astatide ion, At^-, is produced under these conditions. Strong oxidising agents, such as hot persulphate, oxidise astatine to a state which is carried by silver iodate, and from this one may infer the existence of the ion AtO_3^-. There is also some evidence for an intermediate oxidation state AtO^-, produced with moderately strong oxidising reagents. The free element is readily volatile, and may also be extracted from solution with organic solvents. It also has a marked affinity for a metallic silver surface. All of these observations bear out the analogy with iodine, though the observations are made with sub-micro quantities of material which are detectable and measurable only because of the great sensitivity of the methods available for counting α-particles.

FRANCIUM

This element, the missing member of the series of alkali metals, has a somewhat longer history than astatine, for Paneth in 1914 observed that the actinium isotope Ac_{89}^{227} emitted some α-particles, although it decays mostly by β-emission to form radioactinium. Since actinium is an element of the third group of the periodic table, the loss of an α-particle would naturally produce the alkali metal of atomic number 87. The nature of the branching in the decay of actinium has recently been more fully studied by Mlle Perey, who has found that 1·2 per cent. of the disintegrations give α-particles the remainder giving very soft β-particles. This is shown below, and it is seen that the francium isotope is a β-emitter of 21 mins. half-life.
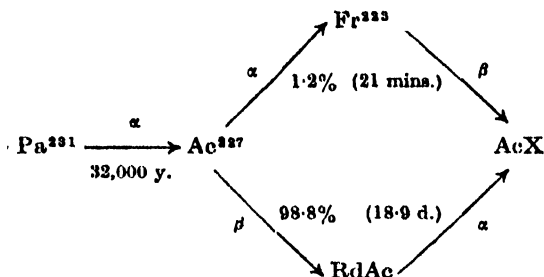
The francium available in tracer amounts from this source was shown to be coprecipitated with rubidium or caesium perchlorates, the hexachloroplatinates of potassium rubidium and caesium, and with the chlorobismuthate or chlorostannate of caesium. These experiments establish the chemical relationship between francium and the alkalis.

The separation of actinium from natural sources is very difficult and the element may be synthesised much more readily from radium by neutron irradiation when the following changes occur :

$$Ra^{226}(n,\,\gamma) \longrightarrow Ra^{227} \xrightarrow{\ \beta\ } Ac^{227} \xrightarrow{\ \alpha\ } Fr^{223}$$
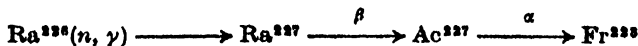
It is probable that future studies of the chemistry of francium will utilise material prepared in this way. It must be pointed out, however, that there is as yet no evidence of the existence of a long-lived francium isotope, nor is it established that non-radioactive francium occurs in nature. There is not, therefore, any immediate prospect that this element will be studied on anything but a tracer scale.

THE BODY ALPHA

AN ESSAY ON THE MEANING OF RELATIVITY *

BY PROFESSOR WILLIAM WILSON, PH.D., D.Sc., F.R.S.

WHEN the distinguished German mathematician, Carl Neumann, was appointed Professor of Mathematics in the ancient University of Leipzig, he discussed in his inaugural lecture, delivered exactly eighty years ago (November 3, 1869), the principles on which the mechanical theory of Galileo and Newton is based [1]. His discussion of old difficulties is almost forgotten now ; but it is of great interest and its main features constitute, as it were, the text on which this essay is a commentary.

Naturally he had much to say about the inertial law of Galileo, familiar to us in the form given it by Sir Isaac Newton (first law of motion). Neumann enunciated it in the following way : " A particle in motion will, if not subject to any external interference, *i.e.* if left completely to itself, continue to move in a *straight line* and will travel *equal distances* in equal times."†

Stated in this way the law, as the lecturer pointed out, is meaningless, since it contains no indication of what is to be understood by *motion in a straight line.*‡ Motion which is rectilinear with reference to a rigid frame fixed in the earth for example will, as he indicated, be motion along a curved line, when referred to a frame fixed in some other planet. In order that the law, as stated, may have a meaning—and it appeared to Neumann that Newton's mechanics was so extraordinarily successful that his laws of motion *must* admit of precise definition and a clear meaning—he contended that there must be somewhere in the universe a special body which can provide a basis for our judgments of motion and in particular

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* The somewhat amplified content of a lecture to the Mathematical and Physical Society of Bedford College on Nov. 3, 1949.

† Ein in Bewegung gesetzter materieller Punkt läuft, falls keine fremde Ursache auf ihn einwirkt, falls er vollständig sich selbst überlassen ist, in *gerader Linie* fort, und legt in gleichen Zeiten *gleiche Wegschnitte* zurück."

‡ Equal distances and equal times also require definition ; but the problems they raise are not very difficult ones.

C. Neumann

for deciding when motion is, or is not, rectilinear. This special body, which he called the body ALPHA, is necessarily perfectly rigid. Neumann uses the word *Körper*, meaning *body* ; but he realises that a suitable set of points (not fewer than three), forming a rigid configuration, will serve (*op. cit.*, p. 26, Note 6) and the existence of his body Alpha appeared to mean for him the possibility of making and using suitable observations to specify such a rigid configuration.

Neumann spoke of velocities relative to his body Alpha as *absolute*—which caused him to be misunderstood by Ernst Mach and like-minded contemporaries [2]—but he was in fact one of the earlier relativists and perhaps the first to enunciate clearly what may be called the *Principle of Newtonian Relativity*. This he expressed by saying that any other rigid frame of reference, moving with a constant velocity of *translation* relative to the body Alpha, serves equally well for the expression of the laws of Newtonian mechanics (*op. cit.*, pp. 21 and 22). Otherwise expressed, the equations of Newton's mechanics *have the same form* in all such reference systems—now sometimes termed *inertial systems*.

It is of interest to re-call that Einstein's earliest statement of his *Principle of Relativity*—later called the *Special Principle of Relativity* —was that the same electrodynamical and optical laws are valid in all co-ordinate systems in which the mechanical equations hold, in other words, in all inertial systems [3]. His earliest approach to the theory of relativity therefore rested on the possibility of *defining* the *ensemble* of inertial systems, and this may be regarded as achieved when one inertial system—Neumann's body Alpha in fact—has been found.

What we learn from Neumann's exposition may be shortly summarised :

(i) It is obvious that Newton's mechanics approximates closely to known facts, though of course we should qualify such a statement today by excepting second order small quantities and microphysical phenomena.

(ii) It indicates the existence of an ensemble of inertial systems capable of definition or specification in terms of observation. We might, for example, start with a system fixed in the earth, when we should find that the axis of a spinning gyrostat—free to turn about its centre of mass—would rotate relatively to our reference system. Our next step would then be to adopt a new system relatively to which the direction of the axis of the gyrostat would remain invariable. In 1913 the Swedish astronomer Charlier observed that the plane of the ecliptic was rotating relatively to

the stars in the Milky Way with a period which he estimated to be 370 million years. Now this plane, like a plane perpendicular to the axis of the spinning gyrostat, is invariable when referred to an inertial system. So the inference was that the stars of the Galaxy are rotating relatively to an inertial system. It appears that we may approach asymptotically towards such a system by observational procedure.

Neumann's preference for assigning priority to a unique inertial system—his body Alpha—rather repels us today ; but we shall see presently how suggestive it is.

(iii) He insisted that physical theory should be based on clearly definable principles rather than on the assumption of the existence —as Helmholtz had preferred—of a system or systems of simple forces (op. cit., Note 9) and he contemplated (under the influence of Riemann's famous essay) the possibility of a continuum of more than three dimensions, the description of which might possibly involve complex numbers—a remarkable intuitive prevision of the development of the relativistic theory of forty years later (op. cit., Note 10, and [4]). The preference for basing physical theory on principles and the elimination of systems of forces from the foundations on which the theory rests was not new in Neumann's day. We meet it in the principle of least action of de Maupertuis (ca. 1745) and in the more complete principle which Sir William Hamilton enunciated some ninety years later [5]. There is no mention of force in these fundamental statements. This does not mean the abolition of the conception of force. Bertrand Russell [6] writes : " The conception of ' force,' which was prominent in the work of Galileo and Newton, turned out to be superfluous and was eliminated from classical dynamics during the nineteenth century." This of course is a misapprehension. Hamilton's canonical equations, for example, which follow out of his principle, contain the rate of change of the components of a generalised momentum, i.e. they provide expressions for a generalised force. Forces, in the old sense, continue to be prominent in the expression of physical relationships ; but they are, one may say, being eliminated from the *foundations* on which physical theory rests.

We now reach the main theme of this essay : the deeper study of Neumann's difficulties, while keeping his body Alpha and his other suggestions in mind ; and it is convenient, at this point, to remind the reader of a rather special group of transformations from one inertial system to another. It is illustrated by two inertial systems of rectangular co-ordinates with co-incident X axes, parallel Y axes and one in motion relative to the other with the constant

velocity, v, in the common X direction (Fig. 1). Assuming the two origins to be coincident at the instant $t = 0$, the equations of transformation are of course

$$\left. \begin{aligned} x' &= x - vt, \\ y' &= y, \\ z' &= z \end{aligned} \right\} \qquad . \qquad . \qquad . \qquad (1)$$

and it is well to add, for the sake of subsequent comparison with the Lorentz transformation,

$$t' = t,$$
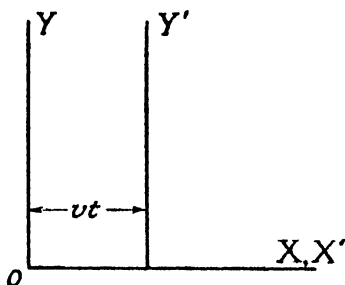
It follows from these equations that

$$\frac{x'}{t'} = \frac{x}{t} - v,$$

or

$$\left. \begin{aligned} u'_x &= u_x - v, \\ u'_y &= u_y, \\ u'_z &= u_z, \end{aligned} \right\} \qquad . \qquad (1a)$$

Fig. 1.

where u_x, u_y and u_z are the components of the velocity of a particle in X, Y, Z and u'_x, u'_y and u'_z the components of its velocity in X', Y', Z'. A very important feature of the transformations of Newtonian mechanics is the fact that the components of vectors transform in the same way as do the corresponding components of a *displacement*. Similarly the components of a state of stress (or also of a state of strain)—there are nine of them—transform like the products of the corresponding pairs of the components of two displacements. All these things are now called *tensors*. Scalar quantities, *i.e.* those which remain unchanged in the transformations which concern us, are tensors of rank zero ; vectors are tensors of rank one ; a system of stresses constitutes a tensor of rank two and so on and the laws of physics are expressed, even in Newtonian physics, by equating the like components of tensors of the same rank. This may indeed be regarded as an alternative statement of the principle of relativity.

Let us now approach Neumann's problems in a somewhat different way, which is, however, suggested by his discussion and by his body Alpha. We ask ourselves : What is the source of his difficulties and those of Mach and others of their time—difficulties which were rendered still more formidable a little later by the experiments of Michelson and his collaborators and by the facts of optics generally and electromagnetism and the incidence of Maxwell's electromagnetic theory ? The answer lies at hand. It is to be

found in the fact of temporal change. If we could contemplate a rigid world—a world in which changes did not occur—difficulties of the type discussed by Neumann would be entirely absent. The whole world would be the body Alpha. This suggests that we should attempt to construct a rigid world which, though rigid and unchanging, will somehow contain our changing spatial one. Clearly this can be done by adding an extra dimension to this latter and assuming the resulting 4-dimensional world to be *rigid*. The extra co-ordinate axis thus introduced may be labelled W and no *formal* distinction will be made between it and the other axes X, Y and Z. A section perpendicular to the W axis represents the spatial world at an instant * and as, in a rigid 4-dimensional world, sections perpendicular to one of the axes, in particular to the W axis, at different points on it, may well be different from one another, we have a way provided for dealing with changes, while still contemplating a rigid world. We shall use the letters x, y, z and w for distances measured along the X, Y, Z and W axes respectively, and naturally we adopt at first the Euclidean type of geometry, associating with it a very obvious hypothesis (which we shall have to modify in a formally trivial degree later) namely

$$w = kt, \qquad . \qquad . \qquad . \qquad . \qquad (2)$$

where t means the time and k is (provisionally) a positive constant.

Our next step is to endeavour to elucidate the significance of the ensemble of Neumannian inertial systems. We must surely find

Fig. 2.

it in the rigid framework of the 4-dimensional world. Let us study the simplest transformation in which the W axis is involved—a " rotation " of X,Y,Z,W into X′,Y′,Z′,W′ about a common origin. Let x, y, z and w be the co-ordinates of some point (point event),

* This suggestion appears in H. G. Wells' *Time Machine* published in the 'nineties.

P, in X,Y,Z,W and x', y', z' and w' those of the same point in X',Y',Z',W' (see Fig. 2). If we confine our attention to the simple special case for which $y = y'$ and $z = z'$, it is clear that

$$\left.\begin{array}{l} x' = x \cos \phi - w \sin \phi, \\ y' = y, \\ z' = z, \\ w' = x \sin \phi + w \cos \phi, \end{array}\right\} \qquad . \qquad . \qquad . \quad (3)$$

ϕ being the angle indicated in the figure.

Points on the W' axis obviously represent—in the old space-time description of physical events—a point which is at rest in the spatial co-ordinate system X',Y',Z', since for such points $y' = z' = 0$ and $x' = 0$ at all times t', for they vanish for all values of w' and it will be recalled that $w' = kt'$. Obviously these points, representing a single point at rest in the spatial system X',Y',Z', must represent one in motion in the spatial system X,Y,Z ; since, as the figure indicates, the larger w ($= kt$), the bigger is x (Fig. 2). Furthermore

$$\tan \phi = x/w = \text{constant},$$
or
$$\tan \phi = x/kt = v/k = \text{constant}.$$

Plainly the two systems, X,Y,Z,W and X'Y'Z'W', represent, in the old space-time language, the two systems X,Y,Z and X',Y',Z', of Fig. 1, with co-incident X,X' axes, the latter moving with the constant velocity, v, relative to the former, in the common XX' direction.

It is easily seen that

$$\cos \phi = (1 + v^2/k^2)^{-\frac{1}{2}} \qquad . \qquad . \qquad . \quad (4)$$

which we may abbreviate by the letter γ ;

$$\cos \phi = \gamma$$

and the figure suggests the positive root. Obviously

$$\sin \phi = \gamma v/k \qquad . \qquad . \qquad . \qquad . \quad (4a)$$

On substituting in equations (3) we get

$$\left.\begin{array}{l} x' = \gamma (x - vt), \\ y' = y, \\ z' = z, \\ t' = \gamma \left(t + \dfrac{vx}{k^2}\right). \end{array}\right\} \qquad . \qquad . \qquad . \qquad . \quad (5)$$

These equations are different from the classical transformation

(1), except when k tends towards infinity, and they lead at once to the following equations corresponding to (1a):

$$\frac{x'}{t'} \quad \frac{\dfrac{x}{t} - v}{1 + \dfrac{vx}{k^2 t}},$$

or

$$u_x \quad \frac{u_x - v}{1 + \dfrac{vu_x}{k^2}},$$

$$u_y' = \frac{u_y}{\gamma\left(1 + \dfrac{vu_x}{k^2}\right)}, \qquad\qquad . \quad (5a)$$

$$u_z = \frac{u_z}{\gamma\left(1 + \dfrac{vu_x}{k^2}\right)}.$$

The suggestion arises naturally that we should enquire about the consequences of introducing the result of the experiments of Michelson and Morley. We therefore assume that the velocity of light in free space—usually represented by c—has the same value in both the spatial reference systems X,Y,Z and X',Y',Z'. Let us think of a beam of light (photons) travelling in the X direction with the velocity c (in the system X,Y,Z). Then $u_x = c$ and $u_y = u_z = 0$. Clearly $u_z = u_s' = 0$ and the Michelson-Morley result therefore requires

$$u_m$$

When this is substituted in (5a) we find $c^2/k^2 = -1$, or

$$\left.\begin{array}{l} k^2 = -c^2 \\ k = \sqrt{-1} \times c. \end{array}\right\} \qquad . \qquad (6)$$

and

Naturally we modify the original assumption about k—as we anticipated we might have to do—by assuming k^2 to be negative and equal, numerically, to the square of the velocity of light in free space. Distances measured along the W axis thus turn out to be imaginary (in the mathematical sense of the term) and, as we have seen, Neumann suggested (eighty years ago) the possibility that a continuum of more than three dimensions might have to be adopted and that its description might involve complex numbers.

On substituting for k in the equations (5) we get the famous Lorentz transformation

$$\left.\begin{aligned}
x' &= \gamma\,(x - vt), \\
y' &= y, \\
z' &= z, \\
t' &= \gamma\left(t - \frac{vx}{c^2}\right)
\end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (7)$$

and of course

$$\gamma = (1 - v^2/c^2)^{-1/2} . \quad . \quad . \quad . \quad (7a)$$

The result of the Michelson-Morley experiment was not the only difficulty which bothered the physicists of sixty-odd years ago. There was another puzzling thing, which in fact was what Einstein dealt with in the paper already mentioned and the study of which led him to the complete form of the old Voigt-Lorentz transformation, given by (7). He illustrated the difficulty by the example of a coil of wire (which we may think of as including a galvanometer in series) and a magnet. If the coil be left at rest on the laboratory bench and the magnet suitably moved in its neighbourhood, the galvanometer indicates a current. The result is precisely the same in every detail when the magnet is left at rest and exactly the same *relative* movements are made by shifting the coil. Such is the fact ; but according to the old interpretation of electromagnetic phenomena the consequences were expected to be different and *in fact* the electromagnetic equations of Clerk Maxwell *do indeed change their form* when we pass from the system in which the coil is at rest to that in which the magnet is at rest *and use the equations of transformation* (1). It was the requirement (Einstein's principle of relativity) that they shall not change their form on transformation from one inertial system to another (combined with the Michelson-Morley result) that brought out the equations (7) and indeed it was this kind of requirement which led Voigt (1887) and later Lorentz to the same transformation, or to one very like it.

We have reached the equations (7) by the study of an older problem and the suggestiveness of Neumann's body Alpha. We were thus led to equations (3), which are (at least formally) equivalent to the Lorentz transformation (7). It was Hermann Minkowski who first introduced the 4-dimensional world picture (described above) as a way of interpreting Einstein's special theory of relativity (1908) [7].

We have in effect constructed a new body Alpha, represented by our rigid 4-dimensional world. It has banished the one unsatisfactory feature in Neumann's original suggestion, since it

comprehends the whole *ensemble* of inertial systems and the unwelcome prominence given to a unique inertial system is now eliminated. Individual inertial systems are now represented by X,Y,Z,W, coordinate systems in the rigid 4-dimensional world which plays the part of Neumann's body Alpha; but we have not yet reached his ideal—abolition of forces as fundamental things (*i.e.* as part of the foundation on which physical theory rests) in favour of principles.

We still have to admit into our foundations, not only a gravitational force and a law of gravity; but also the seemingly quite unrelated electromagnetic forces. The ideal is some general principle from which all these things emerge and which relates them to one another. We have a strong hint as to what form this general principle should take. We find it in the stationary principles, already referred to, of Fermat, de Maupertuis and Hamilton; but before following it up we may note that Newton's mechanical and gravitational theory is thoroughly well housed and represented in the Minkowskian 4-dimensional world. The laws of mechanics still retain the form given them by Hamilton, with a somewhat wider scope. Mass is no longer independent of velocity. In fact

$$m = m_0 \, \gamma, \qquad . \qquad . \qquad . \qquad (8)$$

where m is the mass of a particle, m_0 is its mass when at rest (in the system to which it is referred) and γ is the factor defined by (7a). This relationship was known to H. A. Lorentz and it is a consequence of it, first noticed by Einstein, that

$$E = mc^2, \qquad . \qquad . \qquad . \qquad (8a)$$

where E is the energy of a particle or system and m is its mass. This of course is the famous *mass-energy law*. There is no longer an arbitrary constant associated with the energy of a body or system as there was in earlier times when only differences in energy had a meaning. The reason is that the special theory of relativity leads to

(energy increment) $= c^2 \times$ (mass increment).

Consequently

(energy) $=$ (mass) $\times c^2 +$ (constant of integration);

but obviously when the mass of a particle, for example, is zero it (the particle) is non-existent and we cannot associate energy with it at all. We must therefore take the constant of integration to be zero.

Electromagnetic and optical phenomena fit exceedingly well into the Minkowskian world. Maxwell's equations now retain their form when we pass from one reference system (inertial system) to another.

The famous Fresnel convection formula (convection of light) emerges simply from (5a) and (6). If u_x' is the velocity of monochromatic light, travelling in the common XX' direction (Fig. 1) through a block of glass fixed in the system X',Y',Z', then u_x is its velocity relative to the system X,Y,Z. Now

$$u_x' = c/n,$$

n being the refractive index of the glass for the monochromatic light ; so we have

$$\frac{c}{n} \qquad \frac{u_x - v}{1 - \dfrac{vu_x}{c^2}}$$

from which we get

$$u_x = c/n + v\left(1 - \frac{1}{n^2}\right)$$

when we neglect second order small quantities and the small Doppler change of n as between the two reference systems X,Y,Z and X',Y',Z'. The factor $1 - 1/n^2$ is of course Fresnel's dragging coefficient.

The account of stellar aberration, as given by the theory now being described, is not very different from that given by Bradley who discovered it. Let us suppose an X,Y,Z system of reference at rest relative to a star which is situated, we suppose, on the Y axis at y, this distance, y, being that of the star from the earth. The earth we may suppose to be fixed at the origin of X',Y',Z' (see Fig. 1). It is convenient to consider the instant when the two origins are coincident, as shown in Fig. 3. The old account of aberration represented the light emitted from a star as a stream of corpuscles, they reach the earth at O, travelling with the speed c in the direction of the Y axis, when referred to X,Y,Z. The old transformation (1a) represents them as travelling in the direction
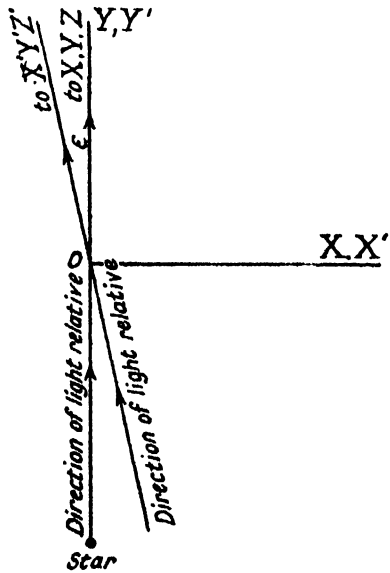
FIG. 3.

indicated in Fig. 3, relative to the system X′,Y′,Z′ (fixed in the earth) with a velocity the components of which are

$$u_x' = -v,$$
$$u_y' = c,$$
$$u_z = 0.$$

The two directions are inclined to one another by the angle ε and

$$\tan \varepsilon = v/c.$$

The only difference between this account of aberration and the modern one lies in the use of (5a) instead of (1a)—it will be recalled that $k^2 = -c^2$—so that

$$\sin \varepsilon = v/c.$$

We may add too that the corpuscular view of light, prevalent in Bradley's day, has been revived in a modified form. A beam of light is a stream of *photons*. Electromagnetic waves still remain with a profoundly different interpretation [5] and there is no luminiferous medium. Before returning to the problem of achieving Neumann's ideal of eliminating systems of forces (in favour of principles) in the foundations of physical theory it may be remarked that the rigid 4-dimensional picture of the physical world has no room in it for those paradoxes, such as the clock paradox, which still continue to give rise to fruitless argument. When we pass from one system of reference, e.g. from X,Y,Z,W to X′,Y′,Z′,W′, we do not in the least interfere with the physical processes which are referred to them, no more than do we interfere with a rigid structure in Euclidean space when we change from one reference system to another. The difference between the w co-ordinates of two points (point events) in our rigid 4-dimensional world has not of course the same value as the difference between their w′ co-ordinates ; or to put it in another way : the corresponding time intervals in the two systems have different numerical values. Bertrand Russell (*op. cit.*, p. 291) describes a form of the so-called clock paradox, which he ascribes to Professor Reichenbach. A rocket projectile travels from the earth to Sirius and takes, shall we suppose, 60 years to do its journey, the time being that appropriate to the system X,Y,Z with its origin fixed in the earth. During that time the passengers, even if they are quite young when they start, will be old when they get as far as the star. If the appropriate value of the factor γ (7a) is, shall we suppose, 6, then the time of the journey, referred to the system X′,Y′,Z′ with its origin fixed in the projectile, will be 60 years divided by 6, *i.e.* only 10 years ! Now Professor Reichenbach's puzzle appears to be that the passengers will find themselves quite

youthful when they arrive, while in fact the earth has revolved 60 times round the sun as observers on the earth would testify. We have reliable information as to the change in the passengers from observations made on the earth, *i.e.* in the system X,Y,Z, and the mere changing of the system of reference, though it makes the time reckoning different, does not cause them to retain their youth.

Let us now turn to the main problem, that of attaining Neumann's ideal. Einstein's greatest achievement was his successful elimination of gravitational force from the foundations of mechanics [8]. It is characteristic of a gravitational field, as Einstein remarked, that it imparts *the same acceleration to all bodies.** It is a consequence of this that a gravitational field can be got rid of locally and temporarily by a suitable choice of a reference system—*e.g.* a reference system fixed in a freely falling lift. Relative to such a system the motion of a particle in the small neighbourhood within the lift and for a short time will approximate to Newton's first law. Moreover, a field with the characteristics of a gravitational field can be created by the choice of a reference system. When the brakes are suddenly applied to a train the passengers in a compartment are projected forwards. Referred to a system of spatial co-ordinates fixed in the compartment, they are in a field of force of the gravitational kind.

Reflections of this kind led Einstein to a new principle which he called the *principle of equivalence,* according to which gravitational fields are of the same nature as those which are created or modified by changing the system of reference. He made progress by adopting a 4-dimensional world which differed from that of Minkowski, already described, in a way which may be shortly indicated by comparing the former to the 2-dimensional continuum represented by a curved surface, a spherical surface for example, and the latter to a plane surface. In the case of the plane surface we can choose a co-ordinate system in such a way that the square of the distance between *any* two specified points is equal to the sum of the squares of the differences of their co-ordinates :

(M) $$(Interval)^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2$$

(theorem of Pythagoras). In such a continuum the *geodesics* are straight lines. A geodesic, it may be explained, is a line with the property that the distance measured along it between two fixed points has a stationary value. In the case of the curved surface, on the other hand, geodesics are not straight lines and the square of the

* First experimentally demonstrated by Sir Isaac Newton and comparatively recently with great thoroughness by the Hungarian, Eötvös.

interval between two neighbouring points has the form

(R) $$ds^2 = g_{11}\ dx\ dx + g_{12}\ dx\ dy$$
$$+ g_{21}\ dy\ dx + g_{22}\ dy\ dy,$$

in which the g_{11}, g_{12}, etc., are functions of x and y. It is however possible to choose co-ordinates in such a way that

$$ds^2 = dx^2 + dy^2$$

within a restricted region which may be regarded as common to the curved surface and a tangential plane one. It is quite easy to see that this is so in the case of a spherical surface. We are of course concerned with a 4-dimensional continuum and the more general one, in which the g_{11}, g_{12}, etc., may have other values (depending on x, y, z and w) than 1 and 0, is usually called Riemannian, after Riemann to whom reference has already been made.

Now Einstein identified the trajectory (world line) of a particle (subject to a gravitational field only) with a geodesic in a Riemannian 4-dimensional world. The stationary principle which determines this and which is usually expressed in some such form as

$$\delta\int_1^2 ds = 0, \tag{9}$$

reminds us of the stationary principles of Fermat, de Maupertuis and Hamilton. Indeed, it is much more general than these and includes all of them within its scope.

Such a statement as (9), applied to Euclidean space, describes a straight line and a particle in a gravitational field moves, according to Einstein's theory, in a way which is *formally* like motion in accordance with Newton's first law. A restricted portion of a Riemannian world may be regarded as coincident with a tangential Minkowski world, just as a restricted portion of a curved surface may be regarded as coincident with a tangential plane and co-ordinates may be so chosen that within this restricted region

$$ds^2 = dx^2 + dy^2 + dz^2 + dw^2.$$

Geodesics in this region are straight lines and in it the motion of a particle is not only formally, but *actually*, in accordance with Newton's first law—when referred to these co-ordinates.

The way in which the components of the fundamental tensor g_{11}, g_{12}, etc., are found can only be indicated here. There is a tensor, the Riemann-Christoffel tensor, which has been known for a century and the vanishing of the components of which is the necessary and sufficient condition that the geometry of the continuum shall have a Euclidean character, like that exemplified by (M) above. A fairly clear notion of what this tensor is like may be

obtained by considering a curved surface for example (a 2-dimensional continuum) and its special case, the plane surface. We imagine a very small (infinitesimal) displacement which we may visualise as a short, very thin rod, ab. This is given a succession of parallel displacements. By this is meant that any two consecutive positions of the rod form the opposite sides of a parallelogram. We think of this as continued till the end a has travelled round a small closed loop and thus occupies its original position. Now in general, though the initial and final positions of a are coincident, the final direction of the displacement which is represented by $a \rightarrow b$ will differ from the original one and it is this difference which the Riemann-Christoffel tensor expresses. Only in the special case of the plane surface—more generally a continuum with the Euclidean type of geometry—do the initial and final displacements, or positions of the imagined rod, exactly coincide and the components of the Riemann-Christoffel tensor vanish.

Einstein derived from this tensor another one which enabled him to find expressions for the g_{11}, g_{12}, etc., and eventually to relate them to the momentum-energy tensor of his 4-dimensional rigid Riemannian world. Mass is just an aspect of this last-named tensor. In fact, it is proportional to the W component of momentum.

We now come to the problem of electromagnetic fields. The most promising suggestion is that of Kaluza [9]. Our body Alpha now becomes a 5-dimensional rigid world and the motion of a particle, charged or uncharged, in the Spatial world is described by the geodesic to which it is confined. The character of this 5-dimensional world is most easily indicated by referring to a small region in it. This of course can be regarded as part of a tangential " plane " world and, with suitable co-ordinates, the interval between two near points has the Euclidean form

$$d\sigma^2 = dx^2 + dy^2 + dz^2 + dw^2 + do^2.$$

Such a small region appears like Minkowski's world with an extra dimension, O, added to it. With such a reference system and within this restricted " tangential " region the components of the momentum of a particle are mv_x, mv_y, mv_z, mv_w and mv_o respectively in the directions of the axes X, Y, Z, W and O and the last of them, mv_o, *is proportional to the charge on the particle.* While in the restricted " plane tangential " region the particle moves in accordance with Newton's first law. A remarkable feature of the theory is that all the conservation principles, conservation of electric charge, conservation of energy or of mass, etc., are included in a generalised principle of conservation of momentum.

Outside the restricted " plane " region the components of the momentum of a particle take the form :

$$\Pi_x = mv_x + eA_x,$$
$$\Pi_y = mv_y + eA_y,$$
$$\Pi_t = mv_t + eA_z,$$
$$\Pi_w = mv_w + eA_w.$$

In these equations A_x, A_y, A_z are the components of the electro-magnetic vector potential and A_w is (apart from the factor $\sqrt{-1}$) the scalar potential [10]. These or. equivalent expressions are a prominent feature of Dirac's electron theory [11]. The fifth momentum component takes the form

$$\Pi_o = eA_o,$$

A_o being a constant and e of course the charge on the particle. Its constancy is associated with the cyclic character of the fifth co-ordinate, o.

Max Planck once wrote, " It only takes a little reflection to realise the fact that the much misunderstood relativity theory by no means gets rid of the absolute but, on the contrary, that it has brought out the absolute into sharper definition " [12]. This *Absolute* appears to be the rigid 5-dimensional world described in this essay. It seems appropriate to name it THE BODY ALPHA.

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THE PRINCIPLES OF SELECTIVE TOXICITY AND THE ACTION OF SELECTIVE HERBICIDES

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INTRODUCTION

THE employment of chemical compounds for the eradication of weeds growing in crops is essentially an exercise in selective toxicity, for a selective herbicide must be able to injure the living cells of the undesirable plant without harming unduly the tissues of the crop. ,

Many of the recent scientific discoveries of economic importance have centred round this problem of selective toxicity. Chemo-therapeutic and pharmacological compounds have been remarkably successful in controlling disease and pain in man and animals. New insecticides and fungicides have greatly reduced the losses caused by pests and diseases. But the sudden expansion of modern selective herbicides is less than ten years old. · It is true that copper sulphate was used over fifty years ago for the eradication of yellow charlock (*Sinapis arvensis*) in cereals, nevertheless it was not until the discovery in 1940–43 that synthetic plant growth-regulating substances could kill selectively both annual and perennial weeds (Slade *et al.*, 1945 ; Nutman *et al.*, 1945 ; Blackman, 1945) that any widespread interest was taken in this field of selective toxicity. Today it is claimed that the study of herbicides is a special branch of agricultural science, equal in importance to the studies of insecticides and fungicides. ,

This wave of enthusiasm, which has swept the world, has brought into being new chemical industries and has stimulated a new outlook on the problems of weeds and their control.· In the United States it has changed the main emphasis of research relating to crop production and is resulting in the discovery of many biologically active compounds, as well as the rediscovery of older methods of cultural and chemical control. ,

As yet many of the compounds and methods of application have

not been adequately tested in the field. Even so there is at present available not only a formidable array of different types of herbicides but also of sheaves of instructions on the methods of application. In fact, the farmer confronted with the claims of the large number of proprietary compounds must inevitably be perplexed.

, In Great Britain, before World War II, weed control was restricted to cereals and the use of either dilute sulphuric acid or copper sulphate ; but this position is now changed almost out of recognition. First, subsequent to 1942, sulphuric acid became in Great Britain a standard practice for weed eradication in onions. Now copper chloride is valuable for weed control in cereal crops undersown with grasses and clovers. Petroleum oils are becoming a standby for weed destruction in carrots and parsnips, 3:5-dinitro-ortho-cresol (DNOC) is particularly effective against some of the main weeds found in cereals and grasses, while 2:4-dinitro-6-secondary-butyl-phenol (DNBP) shows promise for weed destruction in peas and lucerne. Lastly, the most important development of all relates to the two growth-regulating substances 2-methyl-4-chloro-phenoxyacetic acid (MCPA) and 2:4-dichloro-phenoxyacetic acid (DCPA or 2:4-D), which are not only proving highly successful for the control of annual weeds in cereals, linseed, flax and grasses grown for seed production, but are also toxic to many of the perennial weeds of arable land, pastures and lawns.

In the United States and elsewhere, such compounds—particularly the growth-regulating substances—are now being used for selective weed control in maize, rice, sugar cane and a range of horticultural crops. Recommendations have also been put forward for the eradication of crab grass (*Digitaria sanguinalis*) from turf with phenyl mercury acetate, for the control of annual weeds in peas and onions with potassium cyanate and for the killing of couch-grass (*Agropyron repens*) with iso-propyl phenyl carbamate. In addition, mineral oils, with or without the addition of dinitro-phenols or penta-chloro-phenol, are being used for weed control in citrus orchards and elsewhere : 2:4:5-trichloro-phenoxyacetic acid is proving particularly toxic to woody perennial plants, and irrigation channels, waterways, etc., are being kept free from vegetation by means of chlorinated benzenes and aromatic solvents.

Although the empirical approach has over several decades lead to the discovery of many selectively toxic agents, it is only in the last fifteen years that some understanding of the fundamental principles involved has been attained and a stage has been reached when this field can be considered a separate branch of science with the beginnings of its own discipline. Most advance has been made

in chemotherapy, but even here the development of selectively toxic compounds still rests on the screening of a large number of substances of which the choice is determined by a degree of speculation. So far, the discovery of selective herbicides has been almost wholly a matter of chance observation and principle has yet to replace empiricism.

Selective toxicity in a plant community, where the individuals are separated in space, and often in time of growth, has its own particular problems and is in many ways very different from the considerations that arise in the parasite-host association of applied entomology and mycology. The selective toxicity of insecticides, fungicides and chemotherapeutic agents is usually dependent upon metabolic differences between host and parasite, and the selective action holds over a relatively wide range of dose. Most selective herbicides, on the other hand, depend for their effectiveness not only on a difference in toxicity at cell level, but also on all the factors which influence the amount of herbicide which reaches the site of toxic action, and the dose required for selectivity is often critical. In practice most herbicides are applied as dusts or sprays and the degree of toxicity at cell level involves the amount and distribution of toxicant retained by the shoot, its penetration into the plant, the transport within the plant and its possible differential accumulation. Each of these factors will be discussed in some detail and emphasis will be laid on the way in which the plant, the environment and the method of application influence selectivity.

RETENTION

' When a spray or dust is applied uniformly over a mixed stand of crop and weeds, the total amount of herbicide retained by the individual plants is always an important factor in determining the net effect of the application. Before, however, discussing the retention by the aerial parts of the plant and its bearing on selectivity two special circumstances will be considered. The first of these is the technique of application known as " pre-emergence " spraying which was developed initially in England for weed control in onion seed beds (Blackman, 1943). Here the question of retention by the crop does not arise, since the application is made before the crop seedlings emerge above ground. When the weed seedlings appear well in advance of the crop, relatively light doses are applied to the seed bed, so that the foliage of the weed seedlings comes in contact with the herbicide while the shoots of the crop just below ground are protected. In addition to this " contact " treatment there is the " residual " pre-emergence technique in which the

herbicide is applied earlier, remains in the surface layers of the soil and kills the germinating weeds both before and after the crop is up. Selectivity here is dependent on the toxic agent being held in the surface soil, where it is more readily absorbed by the weeds germinating in this layer than by the growing plumule of the crop plant with its roots at a lower level. Thus this technique is most successful for crops with large seeds, which can be sown at a depth of several centimetres. /

' The second special condition relates to submerged aquatic plants in stagnant or running water. Under these circumstances the tissues are surrounded by the medium containing the toxicant and differences in retention play no part in governing any selective action. .

Some selective herbicides, such as the growth-regulating substances, act when applied either as liquids or dusts, but their efficiency in post-emergence treatments is greater as liquids. Moreover, as the majority of the investigations on retention have been concerned with sprays, the following discussion will be limited to spray retention, although it should be realised that under some conditions the differential retention of dusts between species may be greater. _

Spray retention is dependent upon the characteristics both of the plant and of the spray. The characteristics of the spray, such as droplet size, the velocity of the droplets and the surface tension, can be altered while the characteristics of the shoot are relatively unalterable.'

The gross morphological features may have a considerable influence on the quantity of spray liquid remaining on the sh ot. Thus plants, with erect cylindrical leaves, such as the onion, retain less than do the dorsiventral leaves of many dicotyledenous weeds. The distribution and number of droplets are also important, for contact with some parts of the plant may cause greater injury : in dicotyledenous weed seedlings the destruction of the exposed apical bud may cause death, while the basal meristematic regions of monocotyledons are frequently protected by the leaf sheaths. The killing of the apical meristem does not inevitably lead to the death of the seedling. For example, though an application of 3:5-dinitro-ortho-cresol may kill the apical bud of *Urtica urens*, comparatively little spray appears to be retained in the axils of the basal leaves and axillary shoots subsequently develop. On the other hand, it has been observed (Roberts and Blackman, in press) that, with some varieties of peas, aqueous sprays of 2:4-dinitro-6-secondary butyl phenol may collect in the leaf axils and cause severe injury to the stem.

Apart from differences in the size, shape and orientation of the leaves, retention is also dependent on the nature of the leaf surfaces. Fogg (1947) investigating the contact angle between water droplets and the leaf surface has shown that, not only are there large differences between species in the extent the leaves are wetted by water, but there may be a regular variation between different leaves on the same stem (*e.g. Sinapis arvensis*). In addition, he found that in some species there was a diurnal fluctuation which was correlated with changes in the water content of the leaves.

Thus the wetting of leaves, as indicated by contact angle measurements, is determined by a combination of the physical and chemical nature of the leaf surface and the physical characteristics of the spray. The addition of a surface active agent will result in a greater wetting and may also increase retention on leaves with a well-developed waxy cuticle. It has been found, for example, that a greatly increased kill of *Chrysanthemum segetum* can be obtained by adding a wetting agent to spray applications of dinitro-ortho-cresol.

Retention can also be increased by substituting oil emulsions for aqueous sprays, but the effect is dependent on the species. It has been demonstrated that an emulsion containing 10 per cent. of Arachis oil may increase the retention by peas (*Pisum sativum*) threefold, but with *Brassica alba* the increase is insignificant (Blackman, 1950). With oil emulsions, however, there are other complications, since the oil may itself be phytotoxic, penetration may take place via the oil phase, and there is the added factor of the partition of the herbicide between the oil and water components.

The method and means of application will also influence retention. High-pressure sprays may cause young shoots of some species to bend and shed the liquid more readily than those of more rigid plants. Droplet size, apart from influencing the degree of retention and area of leaf covered, may also effect the degree of penetration. For instance, Loomis (1949) records that with some translocated herbicides coarse sprays of relatively high surface tension are more effective than fine sprays of lower surface tension. Although penetration into the leaves is roughly proportional to the area in contact with the droplets, it must be realised that any means adopted to increase retention may tend to make the spray less selective. It has also been found that the overall toxic effect of a fixed dose of a growth-regulating substance varies with the volume of spray applied per unit area (Blackman, 1950).

PENETRATION

⟨ The herbicide may enter the plant through either the root ⟨ the shoot. Considering first penetration into the shoot, entry may ⟨ be through the stomata or through the cuticle into the epidermis. Experiments on hypo-stomatous leaves have shown that with solutions of high surface tension entry through the stomata does not appear to be important (Weaver and De Rose, 1946 ; Fogg, 1948). This result is in keeping with theoretical considerations of the spontaneous entry of liquids into pores of comparable shape and size (Adam, 1948). On the other hand, liquids of very low surface tension, such as mineral oils of low viscosity, may pass through the stomata (Turrell, 1947). With compounds of a relatively high vapour pressure, such as dinitro-ortho-cresol and some esters of dichloro-phenoxyacetic acid, it has been shown that sufficient quantities can diffuse through the stomata to cause toxic effects, but the relative importance of diffusion and penetration through the cuticle has yet to be assessed. It is probable, however, that passage through the cuticle is far more important.

⟨ Crafts (1948) has put forward the generalisation that non-polar substances penetrate through the cuticle most readily and therefore from this aspect are more effective herbicides. However, there is a large bulk of experimental evidence that both non-polar and polar compounds can readily penetrate leaves (Norman *et al.*, 1950). It seems most likely that the mode of entry is basically different between these two classes. Non-polar compounds almost certainly enter by simple solution in, or diffusion through, the lipoidal component of the cuticle and epidermal cell walls. Water-soluble compounds probably enter via the pectinacious and allied hydrophilic substances which have been shown to form a continuous path through the cuticle and epidermal cell walls of apple leaves (Roberts *et al.*, 1948). For this type of penetration it is seemingly essential that the chemical should be in actual solution on the exterior of the leaf. Thus with ammonium 2:4-dichloro-phenoxyacetate penetration almost ceases as soon as the spray droplets have dried (Rice, 1948). Again it has been demonstrated that if a hygroscopic agent is added, the total amount of toxicant passing into the leaf is greater (Hopp and Linder, 1946 ; Rice, 1946). The addition of surface active agents, apart from their effect on retention, may also increase the area of contact and hence the degree of penetration (Staniforth and Loomis, 1949). Lastly, it has been suggested (Innes and Boyd, 1946) that for some toxicants the epidermal hairs may form a ready means of entry, but no rigorous experimentation has yet been carried out. ⟨

Because most of the investigations on nutrient uptake by roots have shown that absorption is principally as ions, it has often been assumed that toxic substances which are readily soluble in water and ionise in solution would be more effective than relatively insoluble non-polar compounds. Sodium chlorate is, for insta ce, absorbed by wheat roots from culture solutions as chlorate ions in the same way as nitrate, and the process is a metabolic one, since the chlorate accumulates in the roots against a concentration gradient (Åberg, 1947). However, many non-polar and slightly soluble substances, such as iso-propyl phenyl carbamate, are absorbed in lethal quantities by the roots of many plant species. Whether the entry of such substances is due to passive diffusion or to metabolic uptake has not been determined.

TRANSPORT

Once the compound has gained entry into the plant, the overall effects will be dependent on its subsequent movement. The evidence to date suggests that copper salts and the alkyl dinitro phenols only move by diffusion, and as this is a slow process only a small area around the point of entry is affected. With other compounds, notably the growth-regulating substances, local application leads to widely distributed toxic effects within the plant and different means of transport are therefore involved. The present evidence is that it is the compound, rather than either a metabolic derivative or a naturally occurring growth substance which has been affected by the original compound, which is freely transported. For example, Wood et al. (1947) have found that 2-iodo-3-nitrobenzoic acid containing radioactive iodine (I_{131}) accumulates in the developing shoots of bean and barley. Weintraub et al. (1950) have produced circumstantial evidence of the presence of 2:4-dichlorophenoxyacetic acid or a dissociable salt in bean shoots from which the originally treated leaves had been removed.

Much attention has been given to the factors which control the movement of growth-regulating substances away from the leaf to which application has been made. In 1946, Mitchell and Brown first showed that transport does not take place if the leaves are kept in the dark for extended periods. They also found that the same effect resulted from treating very young leaves or maintaining older leaves in carbon-dioxide-free air in the light. In snap beans, altering the length of illumination before the application produced variable results which appeared to be correlated with the total sugar content at the time of treatment. In addition, Weaver and De Rose (1946) have found that transport is reduced if much of the

lamina is removed, leaving only the directly treated area connected with the leaf veins.

It must be emphasised that in these investigations evidence of movement away from the leaf has been based on the observed effects on the stem. On the other hand when application is made on the stem the subsequent effects are in no way influenced by whether the plants are kept in the light or the dark. Since Rice's (1948) experiments indicate that the penetration of ammonium dichlorophenoxyacetate into leaves is greater in the dark than in the light, the conclusion is reached that it is the transport out of the leaf that is affected, and this transport is probably associated with the translocation of organic metabolites. Recently, two groups of investigators (Rohrbaugh and Rice, 1949 ; Weintraub and Brown 1950) have reported that if sugars are applied externally to the leaves of beans which have been kept in the dark, then transport of growth regulating substances from the leaf takes place. There are some variations in the effects of different sugars and the two groups of workers do not agree on their relative efficiency. Weintraub and Brown are of the opinion that translocation is facilitated by a general movement of metabolites rather than the movement of some specific sugars.

The transport out of the leaf is presumed to take place through the phloem, since it appears to be restricted to living cells. Nothing is yet published on the mechanism by which the growth-regulating substances reach the phloem from the epidermis. The mechanism may well be complex, especially with water-soluble compounds, because of the suspected presence of a second cuticle on the interior side of the epidermis (Williams, 1950) and the hydrophobic nature of the outer surfaces of mesophyll cell walls (Lewis, 1948).

Once the growth-regulating substance reaches the stem, it can move both upwards and downwards. Acropetal movement can take place through a portion of the stem killed by heat and such movement is affected by the factors which influence transpiration rate (Skoog, 1938 ; Hitchcock and Zimmerman, 1935 ; Ferri, 1945). Basipetal movement cannot take place through a heat-treated portion of a stem and is likely therefore to be associated with the movement of metabolites.

Toxicity at Cell Level

It has already been emphasised that the problems of selective toxicity have been most intensively studied in the development of insecticides, fungicides, drugs and chemotherapeutic compounds, and the concept of a compound operating selectively at cell level is fully

established. Recent work has made it clear that the study of comparative biochemistry is a key to the understanding of many aspects of chemotherapy (Work and Work, 1948 ; Albert, 1950). Thus it is possible to design molecules which will act as antagonists to essential metabolites and so interfere with the normal sequence of the biological changes in cells, but only some of these substances have a selective action (Woods and Nimmo-Smith, 1949). For example, the competition of sulphonamides for the enzyme concerned in the utilisation of para-amino-benzoic acid for the production of folic acid inhibits the growth of some bacteria, but is harmless to mammals which derive their folic acid from food or by bacterial synthesis in the gut. The sulphonamides are selective, but pantothenic acid analogues, for example, are not ; the latter compounds antagonise growth factors that are essential for both bacteria and mammals.

The biochemical differences between mammals and bacteria are large—in fact, far larger than can be anticipated between different species in the same phylem : in particular, between one angiosperm and another. Yet differences in metabolism of different angiosperms do exist, e.g. the special carbohydrate metabolism of succulents, the characteristic nitrogen metabolism of insect catching plants and the specific fat metabolism of latex-containing plants. There is also variation in the chemical constitution of fats, waxes and essential oils in different species, and it is possible to relate some of these differences to geographical distribution, climate and stage of development (McNair, 1934 ; Kurtz, 1950). Some plants can accumulate without injury selenium to a much greater degree than others. It has been found more difficult to culture the excised roots of monocotyledenous than dicotyledenous plants and that moreover the roots of different species demand different nutrients. For example, selections of tomato vary in their vitamin requirements (Robbins, 1941 ; Whaley and Long, 1944). As well as these differences in metabolic uptake and metabolism, it has been shown by Collander (1937) that the passive penetration of organic non-electrolytes into the cell also varies with the species.

From this brief list, it is clear that biochemical differences between plants do exist and that they could, together with bio-physical differences, associated with penetration and partition, be responsible for a clear-cut differentiation between resistant and susceptible plants.

In the elucidation of these fundamental differences there are two approaches. First, detailed comparisons can be made of the physiological and biochemical responses of susceptible and resistant species. Secondly, the precise nature of the toxic effects in a single

species can be studied. Although the first approach can yield a large amount of comparative data, the integration and interpretation of the results can only take place when the nature of the toxic action is understood. In the field of phyto-toxicity, the beginnings of the second approach are only now being initiated and neither approach has given more than a hint of metabolic selectivity.

BIOLOGICAL RESPONSES OF RESISTANT AND SUSCEPTIBLE PLANTS

Some of the most interesting studies are those that have been carried out on respiration. Kelly and Avery (1949) working with sections of the stem of pea and oat, which in the field can be classed respectively as resistant and susceptible species to 2:4-dichloro-phenoxyacetic acid, found that the pea was much more sensitive to the effects of the compound in stimulating and inhibiting respiration.

Somewhat similar experiments are in progress in this laboratory using vacuum-infiltrated discs of the leaves of different species and measuring the respiration effects produced by dinitro-alkyl phenols. Preliminary results again suggest that species differ in their sensitivity at cell level and that such differences can be related to differences in susceptibility in the field.

Another approach, in respect to ethyl phenyl carbamate, has been to study the inhibition of root extension growth and the mitotic aberrations produced in a resistant (pea) and susceptible (barley) species (Ivens and Blackman, 1949). It has been found that in terms of root growth and interference with normal mitosis barley is more sensitive.

Direct evidence of a metabolic difference is forthcoming from the work of Kvamme *et al.* (1949) on lipase activity. From a study of the kinetics of the action of 2:4-dichloro-phenoxyacetic acid they conclude that lipase prepared from the beans of *Ricinus communis*—a susceptible species in the field—is approximately 400 times more susceptible than lipase prepared from the germ of wheat—a resistant species.

Such comparative studies produce wisdom after the event, since it is the last process in the chain that is being investigated, and a true assessment of the nature of selective toxicity at cell level must rest on a proper understanding of the biochemical and physiological processes that the herbicide is controlling.

MODE OF ACTION

For the synthetic growth-regulating substances, the accumulation of knowledge concerning natural auxins is a starting-point for the

analysis of the toxic action.   Apart from the effects of the growth-regulating substances on meristematic activity and cell division, the most widely observed physiological disturbance has been a profound upset in the carbohydrate balance.   Reserve carbohydrates decrease, reducing sugars at first accumulate and then in turn frequently diminish.   The ultimate reduction is as a rule insufficient, however, to justify the conclusion that starvation has contributed to the death of susceptible plants.

Other physiological changes which follow treatment with 2:4-dichloro-phenoxyacetic acid include reductions in the leaf area and total dry weight, changes in the respiration rate, altered vitamin levels in the tissues (Luecke, Hamner and Sell, 1949) and a disturbance in the potassium metabolism of susceptible plants (Rhodes, Templeman and Thruston, 1950).   Further, Nance (1949) has reported an inhibition of salt accumulation, while Smith, Hamner and Carlson (1947) obtained results which lead them to postulate that dichloro-phenoxyacetic acid interferes with the functions of the phloem.

The physiological effects are thus numerous and varied, like those of natural auxin itself.   In fact, many workers consider that synthetic growth regulators operate by altering the concentration of the natural auxin in the cell.   Skoog (1947), for instance, suggests that dichloro-phenoxyacetic acid competes with the natural auxin for the protein centres and thereby releases active auxin from an inactive bound state in a protein complex.   Temporary stimulation may result from this auxin release, but this will ultimately result in a loss of auxin and in extreme conditions the breakdown of the normal auxin-supplying mechanism.   Goldacre (1949) postulates that dichloro-phenoxyacetic acid disturbs the dynamic equilibrium which he considers to exist between the production of indole-acetic acid from tryptophan and its destruction by indole-acetic acid oxidase, and as supporting evidence states that in the presence of the phenoxyacetic acid there is a marked increase in the rate of breakdown of indole-acetic acid.

In this department, the relative toxicity of a large number of nitro compounds has been estimated and particular attention has been given to the 2:4-dinitro-6-alkyl phenols, since it has been found that the addition of two nitro groups and a hydroxyl group to the benzene ring is a highly toxic combination.   In the homologous series ranging from the dinitro-phenol to the dinitro-octyl phenol an alteration in the number of carbon atoms in the side chain does not bring about *major* changes in toxicity when relative toxicity is expressed in terms of the concentrations required (i) to give a

50 per cent. mortality of mustard seedlings sprayed under standard conditions, (ii) to halve the frond multiplication rate of *Lemna minor* grown in culture solutions containing the toxicant, (iii) to halve the growth rate of the mould *Trichoderma viride*, and (iv) to reduce the respiration rate of yeast by 50 per cent. On the basis of Ferguson's (1939) thermodynamic considerations, the " activities " determined by the ratio of the equi-toxic concentrations and solubilities in water indicate that the lower members of this series are acting chemically and not physically. Moreover, since the relative toxicities are of the same order, irrespective of the organism, there are grounds for concluding that they must be affecting some part of the metabolic chain which is common to the several organisms.

Knowledge of the metabolic effects of phenols and nitro-phenols is now accumulating rapidly, but it is as yet premature to outline the nature of the toxic action. It is well known that phenols act as protein-precipitants and this has been held to account for their action as disinfectants. Recent work, *e.g.* Gale and Taylor, 1947, has demonstrated that the bactericidal action of phenols is accompanied by a rupture of the cell membranes and a release of cell constituents into the surrounding medium.

Aryl nitro compounds, especially 2·4-dinitro-phenol, have been used as inhibitors in studies of the cell metabolism of micro-organisms and animals, since they inhibit synthetic activities (anabolism) at concentrations which still allow of respiration or fermentation (Clifton, 1946). The anabolic activities which can be arrested include the assimilation of carbon and nitrogen compounds, the formation of adaptive enzymes, cell division and regeneration. Low concentrations of nitro-phenols stimulate the rates of respiration and fermentation, while higher concentrations are inhibitory (Peiss and Field, 1948). The stimulated respiration is mediated through the same oxidation enzymes as the normal respiration and with the same respiratory quotient. The available evidence suggests that the concentrations which lead to a maximum stimulation of respiration are also those which reduce anabolic activities. In an endeavour to discover the mechanism whereby the energy released in respiration is withheld from synthetic processes, recent work has been concerned with the phosphorylation cycle.

Although on the basis of these many investigations there is a firm indication of a common metabolic action of the alkyl-dinitro-phenols, yet field and greenhouse studies at Oxford of the relative effects of dinitro-ortho-cresol and 2:4-dinitro-6-secondary butyl phenol show that in terms of plant kill the relative toxicity is dependent upon the species. For some twenty species it has been

found that the butyl phenol is more toxic, but the pea is an exception. The most striking comparative data are forthcoming from an experiment in which it was demonstrated that, whereas to mustard (*Brassica alba*) the butyl phenol was approximately three times as toxic as dinitro-ortho-cresol, it was only half as toxic to the pea.

Considered against the whole body of toxicity data that has been accumulated with aryl-nitro-compounds this instance of reversal in relative toxicity is outstanding. It could be postulated that the reversal is due to factors controlling the entry of the toxicant into the cells of the leaf. However, there are some indications that this is not an adequate explanation and an approach at cell level is now being made to discover whether with these two species there are specific differences in the effects of the compounds on respiration and other processes.

This review could be extended to cover the nature of the toxic action of other widely used herbicides, such as the hydrocarbons, cupric chloride and penta-chloro-phenol, but the conclusions would be even more speculative. With chlorates, however, the work of Åborg (1947) and Ekdahl (1947) with wheat plants has indicated that it is not the chlorate in itself which is toxic but the reduction products, chlorite-hypochlorite, produced by the nitrate reduction mechanism. Against such a background, it is possible to speculate whether a plant comes within the resistant or susceptible class. If chlorate poisoning is dependent on the nitrate reduction mechanism, then plants, such as rice, which utilise ammonia nitrogen should be less affected.

In conclusion, no biologist will be surprised that in this relatively new field of selective phytotoxicity, in spite of a decade of extensive research, the facts that have been gathered together still resemble a jig-saw puzzle in which many more pieces will have to be assembled before the ultimate picture takes shape. Until this stage is reached the discovery of new toxic compounds must rest on trial and error, and without field and glasshouse tests the differential reaction of species will remain a matter of guesswork. Once more it is emphasised that the present disarray of the empirical approach will only be marshalled into order by the discipline of a precise knowledge of the toxicity at cell level.

Lastly, the author wishes to stress that this review could not have been written without the help of the other members of the research team working in the Department on various aspects of toxicity. Much of the information and many of the ideas come jointly and severally from E. K. Woodford, E. W. Simon, K. Holly, H. A. Roberts, L. Reinhold, and G. W. Ivens.

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THE CONTRIBUTION OF PETROLOGY TO THE STUDY OF SEDIMENTATION *

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MANY different streams of geological research have contributed to our knowledge of sedimentation and of its products, the sedimentary rocks. In particular the petrologist, by examining significant features of composition, texture and structure of a sediment, whether ancient or modern, the palæontologist, by studying the biological complex associated with it, and the stratigrapher, by tracing its lateral and vertical variations, have together endeavoured to reconstruct depositional environment, palæoecology and palæogeography. Incentive to these studies has been provided by the economic importance of many of the products of sedimentation— for, as Goldschmidt (1937) has pointed out, over 85 per cent. of all valuable mineral products come from the sedimentary rocks. The phenomenal expansion of the petroleum industry during the past fifty years has probably done more than any single factor to encourage the study of sediments, both as the source rocks and the reservoir rocks of oil, and, to a less degree, in the search for possible means of subsurface correlation. In addition, a vast amount of data regarding the processes of sedimentation has accumulated in the course of proving and winning such mineral products as coal, the saline evaporite deposits and the bedded ironstones, while the rapid development of interest in soil mechanics and in ground water hydrology has allied the civil engineer to the geologist in studies of many of the features of the sedimentary rocks.

Sedimentary petrology has now about a hundred years of history behind it. In this country the dominant figure of last century was Sorby, the father of petrography. His first paper on the Millstone Grit of Yorkshire was published in 1859 and twenty years later, in two presidential addresses to the Geological Society (1879, 1880), he set out the fruits of his experience regarding the structure and

* An Inaugural Lecture delivered in the University of London, King's College.

origin of sedimentary rocks. From that time until the publication, just before his death, of a remarkable contribution on the application of quantitative methods to the study of sediments (1908) he consistently led and shaped the development of the science. J. A. Phillips, Sollas, Dick, Wethered, Hume and Teall were quick to adopt and adapt Sorby's technique. In 1902 H. H. Thomas in a classic paper on the Bunter Pebble Bed of Devon showed the illuminating deductions regarding derivation and palæogeography that could be drawn from detailed examination of the minerals present and of their lateral variation in a sediment. Other studies of about the same period, outstanding both for methods employed and conclusions drawn regarding conditions of deposition, were those of Jukes-Browne and Hill published between 1900 and 1904 in the Geological Survey Memoirs on the Cretaceous Rocks of Britain.

Meanwhile, abroad, Retgers completed in 1895 his famous work on the dune sands of Holland. He appears to have been the first to appreciate the possibility of determining conditions of deposition by similar studies of more ancient geological formations. A flood of results poured in from the Italian School where Artini, Chelussi, Clerici, Toni and Salmojraghi were studying the soft sediments of the Lombardy plains. In the main these researches were devoted to improvements in technique and to tracing the sources of individual minerals in the deposits. Strangely, Germany with her great mineralogical and petrographical traditions, had little to contribute to the study of sediments at this period. Thürach and Walther alone carried on a somewhat half-hearted resistance movement against the domination of the igneous petrographers. The balance was, however, to be handsomely redressed in later years by the research inspired by Correns and his co-workers at Göttingen. In France, where pioneer work on methods and on modern sea bottom sediments was carried on by Thoulet from 1879 onwards, the science is dominated by one name. Lucien Cayeux set out to do for sedimentary rocks what had already been done in the field of igneous petrography by Rosenbusch, Michel Lévy and Lacroix. His beautifully illustrated volumes—*Introduction à l'étude pétrographique des roches sédimentaires*, together with the more specialised Memoirs on the siliceous and carbonate rocks, the oolitic iron ores and the sedimentary phosphates (this last uncompleted at the time of his death)—have become the essential works of reference of every sedimentary petrographer. His aim was to unravel the complete geological history of every sediment and though we may reserve judgment on some of his conclusions we cannot doubt the essential

soundness of his methods. It is strange to reflect that at the end of his life he became in some measure dissatisfied with the Lyellian philosophy and that he felt that uniformitarianism had proved wanting in explaining the complex processes of sedimentation.

From 1915 onwards petrological studies of sediments multiplied rapidly in Britain. Interest was in the main centred on the rarer mineral constituents often comprising less than 1 per cent. of the rock. This stage in the development of the science has been fully chronicled by Boswell (1933) who, together with Fleet and Smithson, produced much of the most stimulating work. In addition to improving technique by the introduction of quantitative methods, they demonstrated the use of heavy mineral suites for correlation over limited areas ; or as indices of source and conditions of transport within an old drainage basin and hence as aids in the reconstruction of palæogeography. So enticing were the possibilities of the method that for a time " heavy mineral work " became synonymous with sedimentary petrography and in the detailed study of heavy crops the textures and structures of the rocks themselves tended to be neglected.

On the other side of the Atlantic impetus to the study of sedimentary rocks was provided by the establishment in 1919 of a Committee of the National Research Council in Washington to encourage and co-ordinate work on sedimentation. Among the early fruits of this body's activities was the publication in 1926 of the *Treatise on Sedimentation* by Twenhofel and his collaborators.

Within the last two decades pre-eminence in the study of sediments has been slowly passing to the United States. This is not the only field in which a large number of skilled research workers encouraged by a powerful economic stimulus—in this instance the petroleum industry—have developed and perfected techniques and ideas born in Europe. One consequence has been a flood of quantitative (though not truly statistical) work on such sedimentary characteristics as grain size and shape, degree of sorting, and resistance of different minerals to abrasion. It is inevitable that results of laboratory experiments should in some measure have proved to conflict with those of studies in the field on actual sediments. In nature different processes—for example, abrasion and sorting—are operating together, sometimes working in the same direction, at others partially counterbalancing one another. In the artificial conditions of laboratory experiments these delicate balances cannot be reproduced.

For some years the realisation of the necessity of employing modern statistical techniques in the study of sediments has been

steadily growing. In this country the potentialities of the method have been recently demonstrated in Allen's admirably careful and detailed work on the Top Ashdown Pebble Bed (1948). It is a chastening thought that this is virtually the only paper in British geology where conclusions have been stated throughout in terms of honest mathematical probabilities. Nevertheless, however much we may admire the use made of the statistical attack in this particular instance and welcome the conclusions justifiably drawn regarding sedimentation in the Wealden delta, we cannot but recognise the inherent danger that the tremendous and forbidding amount of laboratory work involved may tend to widen the gap that unfortunately already exists in this country between the sedimentary petrographer and the stratigrapher. The statistical method, capable of providing an answer to problems soluble in no other way, is a weapon to be used sparingly and with discretion, lest, as Russell has recently put it (1949), detailed studies of the bark of individual trees cause us to lose sight of the forest.

The major contribution of the modern school of American sedimentary petrologists has been in the field of facies analysis. Comparative studies of many stratigraphic sequences show certain recurrent associations which are repeated too commonly to be accidental. The Americans have set themselves the task of finding out which textural, structural and compositional features are commonly associated and which mutually antipathetic—and why. Inevitably they have been led to the conclusion that the overruling factor which controls sedimentation is diastrophism—a conception born in Europe and developed in the writings of Marcel Bertrand (1894), Bailey (1936), O. T. Jones (1938) and Tercier (1939) among others. Pettijohn, Krynine, Krumbine and their associates have accepted as fundamental the principle that the tectonic and geomorphic processes which shape the successive stages of development of a land mass must also control, on the broad regional scale, the sediments formed at each stage. These processes determine not only relief and topography surrounding a basin of deposition, but also the nature and intensity of metamorphism and igneous activity, and therefore the material from which future sediments are derived. In addition, through topography they influence climate, and hence the nature of weathering. Conditions of high relief give rise to rapid erosion and deposition with the formation of ill-sorted sediments with poorly rounded grains, containing a variety of both stable and unstable minerals. Conditions of low relief, giving rise to slow erosion and prolonged reworking prior to final burial, produce well-sorted sediments with highly rounded

grains and only the most stable minerals present. In other words, the mature stage of the geomorphic cycle will be accompanied by the production of mature sediments—that is to say those approaching the stable end-state to which they tend ultimately to evolve— while the earlier stages will be accompanied by immature sediments.

The most valuable of all the common minerals as an index of maturity is felspar. Felspar is sufficiently unstable to be absent in quantity from all save the most rapidly deposited sediments. The early work of Judd (1886) and Mackie (1899) had tended to regard felspar as an index of climate—a mineral which could only survive under conditions of aridity or cold capable of inhibiting its decomposition by retarding chemical weathering. Krynine's studies (1935) of arkose formation in southern Mexico under humid tropical conditions, with average temperatures of 80 degrees and annual rainfull of 120 inches, have made it clear that rapidity of erosion and deposition, rather than climate, is the essential factor in the preservation of felspar. Accompanying felspar in the immature sediments we can expect an extensive suite of the rarer and less stable heavy mineral species. In the more mature sediments their proportions, relative to the stable zircon and tourmaline, steadily decrease till at the end stage the heavy crop is dominated by these two minerals. Complications are inevitably introduced by subsequent changes involving authigenesis on the one hand and mineral solution and destruction on the other. The recognition of these effects is part of the responsibility of the sedimentary petrographer (*see* Smithson, 1950).

Krynine (1943, 1948) and Pettijohn (1949) have set out clearly the case for dividing sedimentary rocks into three major suites or clans, each of which is associated with a different stage of the geomorphic cycle. Each clan has clastic representatives ranging from the coarse conglomerates or breccias to the fine-grained muds and clays. Since the medium-grained clastics are more widespread than their coarser-grained associates and more easily studied than the accompanying argillites, their members, the quartzose sandstones, the graywackés and the arkoses are commonly taken as representative of the three clans.

The *quartzose sandstones*—the ortho-quartzites of the Americans —are typical of the stage of maturity where relatively low land masses have been subjected to prolonged and intense weathering, and sedimentation is proceeding in shallow shelf seas—the platform or foreland type of sedimentation. The sandstones of the platform facies are characterised by well-rounded grains of stable mineral species and are commonly accompanied by detrital limestones or

by chemically precipitated sediments. Typically they show wide-spread current-bedding and abundant non-sequences. Second cycle deposits formed through reworking of pre-existing quartzose sediments may be distinguished by such features as the presence of fragments of earlier quartzites or of quartz grains showing abraded secondary growth. The Jurassics of north-western Europe are sediments of the platform facies and their arenaceous representatives have all the characteristics of the quartzose sandstones.

On the other hand the *graywackés* are typical of the geosynclinal stage of the cycle. They are unsorted deposits containing angular or sub-rounded grains of quartz, felspar and a variety of other minerals accompanied by fragments of such rocks as sandstone, quartzite, siltstone, mudstone or slate set in a muddy matrix, commonly converted by low-grade metamorphism to chlorite and sericite. They represent material " poured " into the geosyncline too rapidly for sorting, rounding or mineral destruction to take place, and characteristically they show graded-bedding and slump structures. It has recently been suggested (Kuenen and Migliorini, 1950) that high density turbidity currents have been an important factor in their formation. Typical sediments of the orogenic belts, they are widely represented among the Lower Palæozoics of Wales and the Appalachians, the Jurassics of the Californian Coast Ranges or the flysch of the Alps.

The *arkoses* with their abundant felspar are typically post-orogenic sediments representative of a piedmont facies and the product of rapid erosion of newly elevated mountain chains. More cleanly sorted than graywackés and commonly devoid of interstitial clay, they are frequently current-bedded and associated with their coarser-grained relations, conglomerates with a heterogeneous assemblage of pebbles including much granitic or metamorphic debris. Arkoses are represented by the Torridon Sandstone of Scotland, the Sparagmite of Norway and in part in the Old Red Sandstone and Permian red beds of north-western Europe.

The fine-grained representatives of the three clans are more difficult to study than their sand grade equivalents. Where fine detrital material is present, as is normally the case in argillite members of the graywacké and arkose suites, the quartz/felspar ratio is usually diagnostic. Members of the quartzose sandstone suite, derived from the products of long and deep chemical weathering, may however lack detrital minerals altogether. Thus, according to Sloss, Krumbein and Dapples (1949) the arkosic suite is normally accompanied by felspathic shales, the graywacké suite by siliceous shales and the quartzose sandstone suite by clay shales. The

significance of the clay mineral complex is more obscure and cannot be fully appreciated until more X-ray data on clays are available. Krynine (1948) believes that the clay minerals are proving diagnostic of the three suites and there is certainly some evidence that kaolinite predominates in the arkosic suite, illite in the fine-grained representatives of the graywackés. However, the changes undergone by the clay minerals in the course of transportation and diagenesis are as yet imperfectly understood. Recent work by Grim, Dietz and Bradley (1949) suggests rather tentatively that, while kaolinite is extremely resistant to sub-aerial weathering, it is slowly transformed, under conditions of marine diagenesis, into illite. Its presence or absence may therefore be evidence of environmental conditions of deposition of a sediment rather than of connection with any particular stage of the geomorphic cycle. Pending further studies on the clay minerals, we can to some extent fall back on chemical criteria for distinguishing the fine-grained representatives of the three suites. Alumina is probably the least mobile of all the oxides, while soda is the one most readily removed, and the alumina/soda ratio may therefore, for practical purposes, be used as an index of maturity of the sediment.

While the overriding factor of diastrophism determines which of the three rock suites shall be formed, changing environments within the major tectonic framework control the deposition of, for example, coarse or fine, marine or continental, sediments. Under stable shelf conditions environmental agents may operate on the sediment for long enough to impress their characteristics fully upon it in terms of textural and other features. On the other hand, in a rapidly subsiding geosyncline the time available for sorting action is limited by the rapidity of burial, so that the environmental impress is much lighter.

Although the rocks of the three great clans have, in the main, mutually exclusive space distributions, anomalous associations are often recorded in stratigraphic sequences. Complications are introduced by lack of precision in description or of agreement in definition of rock types. For example, Pettijohn (1949) attaches a more restricted meaning to the term graywacké than Krynine (1948) and distinguishes · as sub-graywackés certain rocks intermediate in character between the " true " graywackés and the quartzose sandstones. These rocks, differing from the " true " graywackés (of Pettijohn) in paucity of felspar, combined with better sorting and better rounding of grains, and in the common presence of an introduced mineral cement, correspond to the low-rank or " common " graywackés of Krynine. They appear to be typical of

the post-orogenic stages of the evolution of a geosyncline and as such, like the Alpine molasse, may spread over the neighbouring foreland to occur in association with the rocks of the quartzose sandstone-limestone suite. Marshall Kay (1949) has criticised the relation of the three clans to separate stages of the diastrophic cycle on the grounds that representatives of all of them can be found at one place or another associated with geosynclinal sediments. These anomalies do not appear to be sufficiently numerous to invalidate the conception as a whole. The occurrence of mixed stratigraphic sections is recognised by Pettijohn and is readily explicable. During periods of temporary stabilisation the shelf sediments may extend out into the geosyncline : while after orogenesis has commenced the reverse may occur. Moreover, such a variety of minor troughs and basins are now covered by the general term geosyncline that considerable variety in the sediments deposited within them is only to be expected.

It is not of course only the major geomorphic cycles which leave their imprint on the sediments. The progress of each individual cycle of erosion is mirrored in the deposits produced during youth, maturity and old age. Uplift at the commencement of a cycle leads to partial destruction of the mantle of weathered material covering the land surface. In the youthful stage relatively level inter-fluves still bear the products of mature weathering, while the sharply incised valleys provide sources of fresh unweathered material. In such circumstances the sediments derived from the area will contain both mature and immature products of weathering. In general the mature products are fine-grained and accumulate mainly in the clay rocks : the immature products are coarser-grained and appear in the standstones. As the cycle progresses and the rate of erosion decreases, weathering goes to completion everywhere, so that only the most stable residues appear in the sediments. Under conditions of almost complete peneplanation little detrital material is derived from the land mass and sedimentation in adjoining basins will be largely chemical or biochemical. Since the sediments are most commonly laid down in the shallow-water shelf areas where reworking due to wave and current action is general, the record is inevitably hard to read, though its interpretation should not necessarily be beyond the power of the sedimentary petrographer.

Various other cyclical processes, many of them as yet unexplained, are clearly reflected in the rocks. The familiar Coal Measure sedimentation is the most obvious example but many others occur throughout the geological column. Alling (1945), using his technique of microlithologies, has attempted to assess sedimentary

sequences on a quantitative basis. By micrometric analysis the percentages of the three principal components of a rock—generally the argillaceous, siliceous and calcareous constituents—are calculated. When these are plotted beside the stratigraphical column there is frequently evidence of rhythmic or periodic variations quite unsuspected from megascopic examination of the section. The seasonal nature of the well-known Pleistocene lake varves with their alternate layers of silt and clay is beyond doubt, and it appears probable that some older rhythmically banded sediments such as the Tertiary Peguan of Burma (Stamp, 1925) also have a seasonal origin. In other cases turbidity currents (Kuenen and Migliorini, 1950), the differentiation of materials during transport or the growth of vegetation (Robertson, 1949) may have been the controlling factors.

The thesis of the American school of sedimentary petrologists is, in summary, that only after the most thorough petrographic analysis can a stratigraphic section, large or small, be fully interpreted. The difficulty of the task will vary according to the facies and lithologies present. The geosynclinal sediments, deposited below wave base, will normally present a more complete record than the deposits of the shallow shelf seas, subjected to constant reworking. The coarse- and medium-grained rocks will always prove easier to deal with than their finer-grained associates. The younger rocks will offer less in the way of problems than the older because of the lessened opportunities for mineral changes due to authigenesis and interstratal solution. In illustration of the necessity for careful petrographic study Krynine (1941) has pointed out the petrological and interpretative disaster that can result from the common mistake of confusing arkoses with graywackés in the field.

Petrographic interest in the glacial sediments seems to have been confined largely to problems of chronology or correlation. Studies of the physiographic aspects of these deposits and their characteristic land forms have not till recently been accompanied by studies of the internal structure of the deposits themselves. Recognition by Richter in 1932 that the pebbles of a glacial till have a statistically preferred orientation which can be studied by the methods of petrofabrics has, however, led to investigations in America (Holmes, 1941, 1949) that are beginning to contribute to our knowledge of glacial deposition. The internal structure of a drumlin is, however, still very much more of a mystery than, for example, the internal structures of a desert sand dune. In the latter field Bagnold (1941), combining the techniques of the sedimentary petrographer and the experimental physicist, has made an outstanding contribution to the study of the mechanism of aeolian sedimentation.

A distinct and fascinating series of problems is presented by the chemical sediments, essentially precipitates whose deposition is governed by the laws of phase-rule chemistry. Grabau (1904) commented that, as the products of crystallisation from solution, these deposits had much in common with the igneous rocks.* Since, however, the reactions involved in the production of the chemical sediments have taken place at relatively low pressures and temperatures, their conditions of origin are far more amenable to experimental investigation.

Clastic and chemical sedimentation are not, of course, mutually exclusive and in fact most sediments are a product of both processes. Indeed, the governing factor for the production of the purely chemical deposits is the exclusion of clastic material from their depositional environment. Though they occur in association with each of the three main rock clans they are typically products of the stable platform areas.

Our knowledge of the mechanism of sedimentation of the chemically precipitated deposits is most complete in the case of the limestones, since the deposition of calcareous sediments can be studied today in the shallow seas of tropical and sub-tropical areas. With the siliceous, phosphatic, magnesian and ferruginous sediments, we have no such advantage and the sedimentary petrographer is generally concerned with the problem whether rocks represent, on the one hand, primary precipitates, or, on the other, metasomatic replacements—either penecontemporaneous or subsequent—of pre-existing calcareous sediments. In many cases a replacement origin has been clearly demonstrated—for the dolomites of the Carboniferous Limestone of Gower by Dixon (1907), for the derived cherts of the Lower Greensand of the Weald by Wells (1947) and for the Permian phosphorites of Idaho by Mansfield (1920).

The origin of oolitic structure has furnished another fertile field for research. The growth of modern ooliths through direct precipitation under conditions of gentle agitation can be observed today off the Florida coast, or in the Gulf of Suez. Microscopic study shows, however, that, though many of the oolitic rocks may have originated in this way, oolitic structure can also result from growth in a colloidal medium. " Necked " or " twin " ooliths, such as those described from sedimentary ironstones by Deans (1935) and Berg (1944), must clearly have developed *in situ* as must the oolitic structure of many bauxites.

The ferruginous sediments present a particularly intriguing

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* In Grabau's day, of course, igneous petrogenetic theory was less advanced than now.

problem, since the vast majority of them represent deposits of a type that are not apparently being formed anywhere under present-day conditions. Indeed, it seems to have been largely as a result of his studies of these rocks that Cayeux became dissatisfied with the strictly Lyellian philosophy. The widespread iron formations of the Pre-Cambrian, superficially at any rate differing from anything occurring in later systems, have helped to give rise to the tacit assumption that the conditions of Pre-Cambrian times were unique. This view has been challenged by Bruce (1945), who has pointed out the wide differences in character of the sediments in the various iron formations, especially between those of Keewatin and Huronian ages. The Keewatin jaspilites are interbedded with coarse gray-wackés and even conglomerates of the geosynclinal suite, while the cherty carbonates of much of the Huronian are associated with the quartzose sandstones and limestones of the platform facies. The complex metamorphic processes to which the rocks have been subjected make it difficult to determine their original nature, but even within the Huronian it seems likely that we may have to deal with iron formations of more than one type. Pettijohn (1943) regards the cherty iron formations of the Pre-Cambrian simply as the equivalents of the rhythmically banded cherts of later periods —some of which, such as the Jurassic Franciscan cherts, are themselves ferruginous. In general, the deep and thorough chemical weathering needed to provide iron in quantity, which is to be expected in the mature stage of the geomorphic cycle, is incompatible with the relief and climate necessary to produce the graywackés of the geosyncline. There appear, therefore, to be grounds for agreeing with those who regard the Keewatin ores as having acquired their iron from hydrothermal sources, connected with the interbedded basic lavas—the "greenstones" which normally accompany the geosynclinal suite.

In the oolitic iron ores of the later formations the same two associations are obvious. The Ordovician ores of North Wales, the Clinton ores of the eastern United States and the Wabana ores of Newfoundland are all geosynclinal sediments. The Jurassic ores of north-western Europe belong to the platform facies. Bedded iron ores are evidently not the product of any one narrowly defined stage of the geomorphic cycle. The major point in which conditions today fall short of those required for iron ore formation is in the absence of the necessary milieu for the precipitation of iron in the ferrous form from natural waters. Microscopic examination of the oolitic iron ores leaves no doubt that in many cases ferrous iron was directly precipitated in the form of carbonates and silicates.

Deposition of ferrous compounds in water appears to depend on one of two things, either on a low oxidation-reduction potential or on a very acid environment (Mason, 1949). It may well be that changes in the Eh and pH of normal sea-water or some as yet unrecognised detail of ionic concentration have been sufficient to account for the accumulation of ferrous sediments in the past. It is, of course, no part of the uniformitarian doctrine that every possible natural process is necessarily operating at the present instant of geological time.

Exceptional opportunities for the geologist to study chemical sedimentation are provided by the saline evaporite deposits. The formation of the limestone, dolomite, gypsum, anhydrite, rock-salt assemblage during three cycles of partial desiccation in the Permo-Triassic rocks of the north of England has been traced in detail by Hollingworth (1942). Until the recent work of Dunham (1948) and Stewart (1949), however, little in the way of purely petrographical investigation of these deposits had been carried out in this country. Such work aims at recognising criteria for the determination of the order of precipitation of the various salts from solution and for distinguishing reactions that occur between early formed crystals and residual liquid from the results of subsequent metasomatism. Purely chemical studies have been more numerous, from the days of van't Hoff's classic work onwards, and have suggested that, at temperatures and pressures within the range shown by existing natural waters, calcium sulphate will first be precipitated as gypsum and anhydrite will only be formed after a high degree of concentration has been attained. Geological evidence, however, shows the presence of much early anhydrite, and microscopical study provides little ground for believing that it is secondary after gypsum. This is clearly a field in which progress can only be made through collaboration between petrologist and chemist.

The carbonaceous deposits afford a rather specialised subject for research—the joint preserve of the palaeobotanist and the coal petrographer. Based on the somewhat conflicting observations and deductions of Stopes (1919, 1935) and Thiessen (1920), there have grown up the so-called British and American schools of coal petrology—neither of them particularly representative of opinion in their own country. The British school recognises a number of " macerals," single fragments or portions of plant debris, which as units can be treated as analogous to the minerals of other rocks and which in varying proportions build up the four lithological types— vitrain, clarain, durain and fusain. These macerals, it is claimed, can be distinguished from one another by the amount of light they

reflect in polished sections (Seyler and Edwards, 1949). The Americans, on the other hand, recognise only two fundamental constituents—anthraxylon, masses of integrated plant tissue preserved as units, and attritus, macerated and degraded plant material. The merit of either technique is a matter of debate, but it can fairly be said that microscopical petrography has played its part in establishing coal as a lithology narrowly defined by certain depositional conditions and in reconstructing the nature of the coal swamp environment.

In reviewing the field of sedimentary petrology one cannot but feel that the interest taken in recent deposits has been less than proportionate to their importance in the study of sedimentation—a surprising fact, in view of the early interest aroused among geologists by Murray's work on the sea-bottom samples collected by the *Challenger* expedition. Possibly the pre-occupation of the earlier oceanographers with the deep-sea deposits—in many ways the least helpful to the geologist in elucidating stratigraphic sections—is in part responsible. So also is the fact that it was only some fifteen years ago with the introduction of the Piggot gun that it became possible to obtain from the ocean bed cores as long as even 10 feet. The rapidity with which technique has advanced since then is shown by the fact that on the Swedish *Albatross* expedition of 1947-48 cores up to 60 feet long were actually drawn with the new Kullenberg piston core sampler. Now for the first time it is possible for serious studies of stratification, rates of sedimentation and diagenesis to be commenced.

To measure rates of sedimentation it is essential first to establish a time scale, and unfortunately in dealing with the relatively short periods represented by deep-sea cores it is not possible to use the slow disintegration of uranium into stable end products in the normal way. However, within the half-million odd years required for the elements of the uranium 238 series to attain radioactive equilibrium, the variation of the radium concentration at successive levels below the ocean bottom affords a method of determining age of the sediments. With this aid it is proving possible not only to estimate rates of deposition but to correlate climatic changes reflected in the ocean sediments over wide areas. Urry's work on deep-sea cores at the Geophysical Laboratory in Washington (1942, 1948, 1949) seems likely to lead to fundamental conclusions regarding the synchronisation or alternation of the Pleistocene climatic changes in northern and southern hemispheres. This and other recent advances in the geological aspects of oceanography have been ably reviewed by Wiseman and Ovey (1950).

One of the most important results of investigation of deep-sea cores has been the information gained of the environment in which diagenesis takes place. This environment is in almost all cases strongly reducing and moderately alkaline. Diagenesis still remains a difficult aspect of sediments to study owing to the considerable period of time normally required for lithification ; but with the long cores now available there is every prospect of progress being made.

Many modern sediments other than the deep-sea deposits have now been investigated. Studies that have become classical are those of oolite formation and deposition of arragonite mud on the shallow submarine platforms of Florida and the Bahamas ; of the precipitation of saline deposits in the gulfs of the Caspian Sea ; and of the deposition of black muds in the land-locked waters of Norwegian fjords and the Black Sea. Detailed investigations of the shallow-water sediments of the continental shelves are a relatively recent innovation arising in part from the increased interest of oil companies in the possibility of production in such areas. Already they have done considerable damage to the old-established conception of coarser in-shore deposits passing into successively finer-grade material out to sea, and it may be that not all of the palæogeographic maps based on the distribution of so-called " littoral " facies will stand the test of time. It seems highly probable that, in the next decade, work on sea-bottom sediments will be responsible for some of the most spectacular advances in geology.

The present time seems an appropriate one for taking stock of the petrologist's contribution to the study of sedimentation and for looking towards the future. Some steps to this end were taken at an informal gathering of sedimentary petrologists after the XVIIIth Session of the International Geological Congress in London in 1948 (*see* Allen and Doeglas, 1949). At this meeting Doeglas expressed concern lest elaboration of laboratory techniques should lead to too narrow specialisation. In his view the greatest failure in sedimentary petrology in recent years had been the relative lack of field work and the exaggerated importance given to laboratory work. Almost identical views were expressed by R. D. Russell (1949) in his Presidential Address at the 23rd Annual Meeting of the Society of Economic Palæontologists and Mineralogists at St. Louis. He feared that in the enthusiasm for the development of quantitative laboratory techniques the study of sedimentation in its broader aspects might suffer. Allen, on the other hand, has seen the danger that in a " back to the field " movement the precision of laboratory methods may be lost. Rightly viewed these attitudes are not

conflicting but complementary. In the closer integration of field and laboratory studies the sedimentary petrologist will be following the tradition of Sorby.

In few branches of the science can the disease of over-specialisation be more dangerous than in the study of sedimentation. So much of our knowledge of geological history comes from the sedimentary rocks that the subject provides a common meeting-ground for workers in many different fields of geology. The sedimentary petrologist can ill afford to cut himself off from his colleagues the stratigrapher, the palæontologist, the oceanographer, the physical chemist and the X-ray crystallographer, for their knowledge or skill are all in some part essential to a complete understanding of the evolution of the sedimentary rocks. Lyell wrote in his *Principles of Geology* in 1830 : "It would be . . . desirable that a geologist should be well versed . . . in every science relating to organic or inorganic nature. . . . But as such extensive acquisitions are scarcely within the reach of any individual, it is necessary that men who have devoted their lives to different departments should unite their efforts ; and as the historian receives assistance from the antiquary and from those who have cultivated different branches of moral and political science, so the geologist should avail himself of the aid of many naturalists." In no field is the aid of " many naturalists " more necessary than in that of sedimentation.

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THE MAIN GEOMAGNETIC FIELD

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WHILE much progress has been made in the last century in the study of the ephemeral changes in the geomagnetic field, so that the broad outline of the mechanism responsible for the solar quiet day variation, for instance, is known, the origin of the main field and the considerable change it experiences in the course of a century (the secular variation) still elude explanation. Accounts of the theories which had been proposed up to that time were given in the two standard treatises on geomagnetism published a decade ago (Chapman and Bartels, Fleming (ed.)). These theories were either at variance with what was known of the Earth's interior from other studies or were too fanciful to attract much attention. Since then new experimental and theoretical approaches have been made, an account of which forms the subject of the present article.

Studies in this field have been greatly assisted by the publication by Vestine and his collaborators (1947 and 1948) of a very complete set of values of the geomagnetic elements and their rates of change over the Earth's surface at various epochs between 1905 and 1945. Vestine analysed the main field, by methods made familiar by Gauss and others, and showed that at least 99 per cent. of the field has its origin in the interior of the Earth.

In his work on the secular change of the field Vestine demonstrates quite clearly two features of great importance. Firstly, his' charts showing the lines of equal annual change in any element of the field (the isoporic lines) emphasise the regional nature of the secular change. The lines are grouped into about ten regions consisting of a series of closed curves centring on foci where the changes are most rapid. Secondly, the maps showing the secular change at different epochs reveal that the isoporic foci drift westwards at about 0·5° longitude per year. The magnitude of the secular change may be as much as 10^{-3} gauss per year If the field of that dipole at the Earth's centre which best fits the observed field is subtracted from the latter, the residual or non-dipole field remaining may be

as great as 0·15 gauss. Consequently, the residual field is considerably changed by the processes of secular variation in the course of a century. As the patterns of the residual field and the secular change are similar and as the foci of the residual field show a westward drift, it is reasonable to suppose that both the secular change and the residual field are caused by similar processes.

A process which could produce appreciable changes in the geomagnetic field in the course of such a short period as a century is not likely to be found in the outer layers of the Earth. However, the evidence from seismology shows that the Earth possesses a core which does not permit the passage of the shear (or S) earthquake waves. This core, whose radius is 0·55 of that of the Earth, must therefore be a liquid with a viscosity sufficiently low for a shear wave to be completely damped in distances small compared with the diameter of the core. Thus an upper limit to the viscosity can be calculated and is approximately 10^6 poises. Frenkel (1945) suggests that it may be as low as 10^{-2} poises, the value of the viscosity of water under ordinary conditions. Elsasser (1946, 1947) saw that a liquid core, which might be expected to have a fairly high electrical conductivity, would have considerable magnetic effects and that motions in the fluid of the order of 0·01 cm./sec. might be sufficient to produce the magnetic secular variation. Bullard (1948) studied a part of the area of rapid secular change in the region of South Africa and showed that it could be well represented by a horizontal dipole at the surface of the core. He suggested that, as a dipole magnetic field could be produced by the rotation of a spherical conductor in a uniform magnetic field, this part of the secular variation might be explained as the decay or other change of an eddy in the fluid just beneath the surface of the core. All the areas of secular change might be similarly explained, for McNish (1940) showed that the secular change field could be well represented by changes in the magnitude (of $1·4 . 10^{22}$ c.g.s.e.m.u. per year) of thirteen radial dipoles at the surface of the core.

As in so many problems in geomagnetism, the vital question is not whether the proposed mechanism will produce a field but whether it will give a sufficiently large one. No effect can be produced greater than the one obtained when the material is rotating so fast that the lines of inducing magnetic flux are almost completely excluded from the material by a distribution of currents in the skin. In such a condition the material acts as if it were entirely diamagnetic and the induced field then depends directly on the volume of the rotating matter. Bullard showed that the main field of the Earth at the surface of the core would probably not have a

sufficient value to explain the secular change by an eddy of reasonable size. A rough calculation will illustrate this difficulty. Assuming that a centre of secular change persists for about a century, McNish's analysis implies that there should be 13 dipoles, each of approximate magnitude 10^{24} c.g.s.e.m.u., formed by induction within the core. Assuming that the field at the surface of the core is about 3 gauss we can calculate the volume of the eddy required to give a dipole of 10^{24} c.g.s.e.m.u. It is about 3.10^{24} c.c. and for the 13 dipoles we should need a volume of 4.10^{25} c.c., only just under one-half of the volume of the core. It therefore seems a little difficult to explain the secular variation and non-dipole field without finding some way of amplifying the main field within the core.

The mechanism by which the motion of a conducting fluid can magnify the magnetic field in a region is best understood by assuming the liquid to have infinite electrical conductivity. Then there must only be an infinitesimal relative motion between any element of moving fluid and the magnetic field component perpendicular to the direction of its motion, otherwise an infinite electric current would flow. Thus the magnetic lines of force are dragged laterally with elements of fluid ; the lines of force are often said to be " frozen into " the fluid. Where the fluid motion is of a complex nature the lines of force will be much kinked and thus lengthened, so that on an average over the whole region of moving fluid there will be more lines of force crossing any unit surface area, *i.e.* the field intensity will have increased.

An example of this process is the toroidal field. If a spherical conductor surrounded by an insulator is spun in a uniform magnetic field along its axis of rotation, the induced electromotive forces cause a transient flow of current, which builds up a surface charge distribution on the sphere. The field of these charges neutralises the induced field and no steady current flows. But if the rotating sphere is surrounded by a conducting shell, either at rest or moving with a different velocity, steady currents can flow. Bullard (1949) showed that, if the core were rotating at a different speed to the mantle so that there was a gradient of angular velocity in the boundary layer, electric currents would flow in meridian planes, producing a toroidal field with the lines of force running round inside the core along lines of latitude and reversed in the two hemispheres. This is shown in Fig. 1. Bullard suggests that interaction between the main field and a differential motion of about a hundredth of a cm./sec. between the main part of the core and its boundary layer might produce fields of tens of gauss in the core.

It is next necessary to consider the significance of Vestine's discovery of the westerly drift of the centres of the secular variation. As might be expected, there is evidence to show that the foci of the non-dipole part of the main field also show a steady drift to the west. Long ago Bauer (1895) computed the value of the angle of dip to be expected from a dipole field and subtracted these values from the observed values for 1780 and 1885. Lines of equal value of the difference, which he called isapoclinics, form two sets of closed curves centring on two points of greatest difference, one in the Atlantic and one in the Eastern Indian Ocean. Both these points moved appreciably between the years 1780 and 1885 at an annual rate of about 0·2° of longitude per year. Bullard (1950) has carried out

Fig 1 — Lines of force of a toroidal field

an analysis of the data gathered by Vestine and has shown that between 1905 and 1945 the annual drift of the non-dipole field was about 0·2° of longitude.

If both the non-dipole part of the main field and the secular variation are due to current systems in the upper part of the liquid core (at least the secular variation must come from near the surface of the core because of the shielding effect of the conducting matter) it is likely that the whole current systems are carried along with the surrounded fluid. Thus Elsasser (1949) assumed that the westerly drift found by Vestine indicates that the Earth's core is moving westwards relative to the mantle, that is, it is rotating more slowly than the mantle. This is surprising because the only torque which is known to influence the rate of rotation of the Earth is that due to tidal friction, which causes a secular decrease in the angular velocity of the Earth, so that it might be expected that the core would be rotating faster than the mantle, if the viscosity of the fluid core were not too great.

Bullard (1949) suggested that the presence of a small amount of radio-activity in the core might give a radial temperature gradient sufficiently high to exceed the adiabatic gradient and so cause convection. This would continually bring matter from the inner part of the core having a slower transverse velocity and therefore reducing the angular velocity of the outer core. However, the mechanism of this process is most obscure.

If there is a differential rotation between core and mantle and if

there is large-scale thermal convection, important magnetic effects will result. The interaction between the main dipole field and the differential rotation will produce a toroidal field.

Bullard proposed that the interaction between these two core motions and the magnetic fields they produce from the dipole field might cause a chain of interactions which can reinforce the dipole field. It was shown long ago by Lamb that if the Earth's field is produced by current flow there must be a mechanism to maintain it, for the time of free decay of such currents, despite the large radius of the Earth, would be small compared with the geological age of the Earth. The circumstances in which motions in a conducting sphere can build up or reinforce an existing field have not been fully discussed. Bullard and others have drawn analogies between the supposed action of such motions in a sphere in reinforcing the dipole field with the build-up of a field (initially small) by a self-excited dynamo. A unipolar generator is shown in Fig. 2. The rotor is a conducting disc and when it is rotated in a small axial field, a radial current flows, which is led off through an axial solenoid wound in such a direction as to reinforce the field. It should be pointed out that the large number of interfaces between insulator and conductor allow surface charges to build up and the resulting electric fields cause currents to flow in the desired
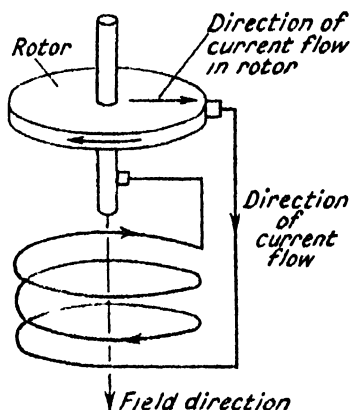
Rotor

Direction of current flow in rotor

Direction of current flow

Field direction

Fig. 2.

directions. In a sphere, where charge distributions can only build themselves up on a single surface, it is not easy to see how conditions similar to those in a generator establish themselves.

An entirely different approach to terrestrial magnetism was taken up by Blackett (1947, 1949) and Babcock (1947), reported in SCIENCE PROGRESS (1947, **35**, 661). The recent discovery by Babcock of magnetic fields of the order of kilogauss in certain A type stars reopened the possibility, originally considered by Schuster and H. A. Wilson, that the magnetic fields of the Sun and the Earth might be examples of a new law of nature in which all rotating masses have an associated magnetic field. In view of the attempts in the last twenty years to construct unified field theories of electromagnetism and gravitation, any suggested connection between cosmic magnetic fields and rotation are of considerable interest.

Blackett suggested that the magnetic dipole moment (P) of the various bodies was related to their angular momentum (U) by the empirical relation

$$P = \beta . \frac{G^{\frac{1}{2}}}{c} . U,$$

where G is the gravitational constant, c the velocity of light and β a constant of the order of one. Such a relation may be fortuitous or might arise because the physical processes by which the magnetic fields are generated are similar. But if a fundamental law, it leads to conclusions which can be tested. Assuming the relation may be extrapolated to laboratory conditions a small field (of the order of 10^{-9} gauss) is to be expected near a sphere of metal a metre in diameter rotated at breaking stress and, making further assumptions, a similar field should be found near a stationary sphere, due to its rotation with the Earth. Also, as Bullard pointed out, the distribution of field within the Earth on this hypothesis would be different from that of other theories. Most other theories assume that current flow in the core produces the field. For such core theories the dipole magnetic field would increase inwards according to an inverse cube relation until the surface of the core was reached. The fundamental hypothesis, as was worked out in detail by Runcorn (1948) and Chapman (1948), leads to a field distribution in which the horizontal component of field decreases with depth inside the Earth, ultimately reversing in sign. The vertical component would increase as a dipole field only for small depths and then would increase less rapidly. These results arise because on a fundamental hypothesis each rotating shell of matter has to produce a magnetic field, and it seems reasonable to suppose that it produces a field similar to that produced by a shell in which electric current flows along lines of latitude. Then, as shown in Fig. 3, the effect of a single shell is to produce tangential components of field in opposite directions within and outside the shell. It can be shown that the decrease in horizontal field this produces

FIG. 3.—Magnetic effect of outer shell for fundamental theory.

inside the shell must outweigh the cube law increase of the field. In Great Britain the difference between the field values at the surface and 4000 feet deep are given by the table on the next page.

Differences in	Core Theory	Distributed Theory
Vertical component (ΔZ) (increasing with depth)	$+ 25 \gamma$	$+ 25 \gamma$
Horizontal component (ΔH) (increasing with depth)	$+ 11 \gamma$	$- 23 \gamma$

1γ (10^{-5} gauss) can be measured by delicate instruments. It is possible in a few deep coal-mines to find passages far enough away from man-made disturbances to measure the true field to an accuracy of 1γ. It is therefore possible to test the fundamental theory by direct measurement. The Earth's field fluctuates during a day, through current flow in the ionosphere, by amounts of the order of 50γ. Thus while the measurements of the difference in the components above and below ground are being made, an instrument must be maintained at the surface to enable corrections to the results for the diurnal variation to be made. The variation with depth, mentioned above, refers only to the dipole field and the measurement of the gradient in practice may very well be complicated by the anomalous gradients due to the magnetism of the underlying geological strata. Extensive measurements have been made in English mines (Runcorn and others, 1950), in the course of which methods have been evolved for making certain that measurements of the field differences between the surface and underground are due to the main dipole field and not to local anomalies.

Over most of the world layers of sedimentary rocks, some thousands of feet thick, have been deposited under water on top of the granitic " basement." Very often the sedimentary beds lie in uniform horizontal layers whilst the granites are highly contorted. The granites contain a high proportion of magnetite and are strongly magnetised both permanently and by induction in the Earth's field. The sediments are often only weakly magnetic. Therefore the anomalous gradients in the field at the surface tend to be related to the structure and properties of the basement rocks rather than to those of the sedimentary rocks. Presumably undulations and horizontal changes of intensity of magnetisation of the basement rocks give rise to the gradients of the magnetic field at the surface.

Thus if an attempt is made to measure the radial variation of the main geomagnetic field through the upper section of the sediments, the magnetic properties of the sediments should not greatly affect the results, but the gradients due to the basement rocks may be very important. Provided that the depth of the mine is small compared to the depth of the basement rocks, we can expect the local magnetic gradients to be linear over distances at the surface

of the order of the depth of the mine. The magnetic field vector is solenoidal and in the absence of current flow it is also irrotational. There are then four equations connecting gradients of the three field components vertically and along E.–W. and N.–S. lines at the Earth's surface. Thus by measuring the gradients along the surface in the vicinity of the mine and subtracting from them the calculated gradients due to the main dipole field of the Earth, that part of the difference in the field at the surface and underground which is due to the basement rocks can be calculated and, if not too large, allowed for. Thus the experiment must be performed in an area where

(1) the basement is sufficiently deep relative to the depth of the mine ;

(2) the sediments in the district are only weakly magnetic ;

(3) the surface gradients are linear in the region of the mine.

Preliminary measurements of ΔH and ΔZ were made in mines in South Africa and in Lancashire, but where the above criterion could not be entirely satisfied. Later experiments (Runcorn and others, 1950) give results for three mines in South Lancashire and Yorkshire. These results give ΔH very nearly equal to that predicted by the Core theory and significantly different from that predicted by the fundamental theory.

Meanwhile attempts have been made to extend our knowledge to the variations of the geomagnetic field into the remote past. Johnson, Murphy and Torreson (1948) have examined the remanent magnetic polarisation of varved clays formed in glacial lakes. As the magnetite particles sink to the bottom of the lake, they are oriented into the direction of the magnetic field at the time. Thus they give to the varves a magnetic polarisation which, as can be shown in the laboratory, is not easily disturbed by subsequent field changes. These clays can be dated by radio-active means and, as coarser particles are deposited in the winter than in the summer, the magnetic changes can be followed from year to year. These workers find that the declination in New England between 15,000 B.C. and 10,000 B.C. wandered about a mean of 5° West of North with maximum excursions of 20° East and 37° West. There was some suggestion of a 300-year periodicity. They also show, from measuring the intensity of polarisation of clays artificially deposited in the laboratory in magnetic fields of various strengths, that the magnitude of the Earth's field when these clays were deposited was not very different from what it is today. Torreson and others (1949) extended the work to the remanent magnetisation of undisturbed sedimentary rocks and found that the frequency curve of the values of declination, in samples whose age distribution stretched over 50,000,000

years, shows a very marked peak at 0° declination. These results would seem on the whole to indicate that the behaviour of the Earth's field as recorded over the last few centuries is typical of its behaviour over a very much longer time. However, there are examples in the Pilansberg dykes of South Africa and in the tholeiite dykes of North England (Bruckshaw and Robertson, 1949) of igneous rocks which show a magnetic polarisation opposite to the present direction of the Earth's field. The most direct interpretation is that, at the time the dykes solidified, the geomagnetic field vector was in the opposite direction to what it is at the present day. But while these abnormal magnetisations have only been found in these rather unusual geological formations it is doubtful whether the explanation is not to be found in the local conditions prevailing at the time of the formation of the dykes.

Johnson and others (1948) showed, by comparing the intensity of polarisation of clays laid down in known fields with that of the varved clays, that the value of the Earth's field at about 15,000 B.C. was not much greater than its present one. These results definitely rule out the possibility that the Earth's field is freely decaying, for, from what is known of the conductivity of the core, the time constant of free decay would work out at about 10,000 to 20,000 years. The spatial and temporal variations of the Earth's field therefore rule out the possibility that certain theories are true rather than provide a key to the solution of the problem of the main field. In a field such as this, it is most important that those theories which have been proposed should be worked out in detail to the point at which their requirements may be checked against what is known from other branches of Geophysics. Much progress has yet to be made before this will be possible with respect to theories involving thermo-electric e.m.f.'s in the core or amplification by fluid motion.

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LEAF MORPHOLOGY AND
PHYSIOLOGICAL AGE

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A STUDY of the literature on heterophylly in flowering plants convinces the reader that leaf shape is controlled by internal as well as external factors. For instance, the progression of leaf shapes in successive leaves of *Sagittaria sagittifolia* and the reversion to juvenile foliage in cuttings of *Campanula rotundifolia* are not responses to the external environment, but to the level of some nutrient or hormone in the meristems themselves. These familiar phenomena, coupled with the fact that there are in most plants consistent changes in shape from leaf to leaf up the shoot, which sometimes seem to be related to its maturity, have raised in the minds of botanists the hypothesis that the physiological ageing of a plant (as contrasted with its ageing in time) might be measured by the changes of leaf shape from node to node. The history of this hypothesis was recently summarised (Ashby, 1948a), and in the last three years experiments have been carried out which enable the hypothesis to be more clearly formulated. It is the purpose of this article to give a brief account of the results of these experiments.

The experiments fall into two groups : the first are studies on the anatomy and morphology of leaves in *Ipomœa cærulea* and *I. purpurea* ; the second are studies on the anatomy and area of fronds in *Lemna minor*. The experiments do not utilise any fresh techniques , their main contribution to the question is that they measure quantitatively some of the changes in morphology from leaf to leaf, and they enable these measurements to be plotted against time.

The experiments began with a study of the gradients of diminishing cell size from leaf to leaf up a shoot, already familiar from the work of Zalenski (1904) and Yapp (1912). It was formerly supposed that these gradients were due to increasing competition for water among leaves, on the assumption that lower leaves on a shoot

deprived the upper leaves of water and thereby created in the upper leaves conditions for xeromorphic development. Experiments on *Ipomœa* (Ashby, 1948b) indicate that this supposition is incorrect. The experiments confirmed the observation of Alexandrov, Alexandrov, and Timofeev (1921), namely that the removal of all the leaves on a shoot causes the next developing leaf to have abnormally large cells. But the experiments went on to show that a similar response of cell size in the next developing leaf can be obtained by removing only the three or four immature leaves below the apex, and that the response cannot be obtained by removing only the adult leaves below the apex. In other words, the removal of some 10 cm.² of actively growing leaf surface has a significant effect on the cell size of the next leaf to develop, whereas the removal of some 250 cm.² of adult leaf surface has no effect on the cell size of the next leaf. On these grounds it was suggested that the gradient of cell size from leaf to leaf in a shoot of *Ipomœa* is determined not primarily by the water economy but by an effect from the three or four immature leaves below the apex. The effect might be that these immature leaves monopolise some inorganic nutrient which ascends in the transpiration stream, but it is much more probable that the immature leaves produce some hormone-like substance which inhibits the expansion of the leaves above them. The experiments are consistent with the view that the apical meristem undergoes systematic changes as it becomes older, and that these changes are reflected in the cell size and cell number of leaves produced at the apex.

These experiments left many questions unanswered, in particular the question as to whether the upper leaves of a shoot have smaller cells than the lower leaves, merely because they develop later in the season. This possibility—that the gradients in cell size and morphology of leaves reflected nothing more than the transition from spring to summer weather—had not been excluded by the experiments of any workers in this field. Accordingly an experiment was carried out to separate the effects on cell size of the two variables : the position of a leaf on the shoot, and its time of appearance in the season. The variables were separated by raising lots of *Ipomœa* at weekly intervals, arranging the plants randomly in a heated glasshouse, and taking observations (a) of cell size and cell number of leaves which unfold simultaneously, but at different heights of insertion on the shoot, and (b) of leaves at the same height of insertion, but unfolding at different times in the spring and summer. The results of this experiment (Ashby and Wangermann, 1950a) were unambiguous. One example of them is illustrated in

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Fig. 1. It is evident from the figure that cell area in a leaf is affected both by the insertion of the leaf on the shoot and by the time of year at which the leaf unfolds; but these two variables affect cell area in different ways. It can be concluded with confidence that the gradient of cell area from node to node is due to some cause internal, not external, to the plant.

The next step in the analysis was to discover at what stage of development the cell size of a leaf is determined. For this purpose a study was made of the mean area of epidermal cells corresponding
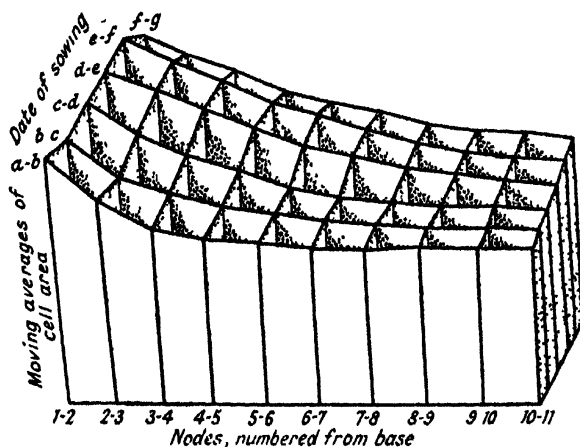
FIG. 1.—Three dimensional graph, showing relation between cell area in the adaxial epidermis of a leaf, level of insertion and date of sowing of the plant on which the leaf grows

Ordinates empirical values for cell area, left to-right abscissae nodes, numbered from base, front to back abscissae, dates of sowing

(By courtesy of the Editor of the " New Phytologist" and the Cambridge University Press)

to leaf area for different stages of development, from leaves just differentiating in the bud (area 0·04 cm.²) to adult leaves (area 40 cm.²). The results (Ashby and Wangermann, 1950b) are that the differences in cell size which distinguish a second leaf (for instance) from an eighth leaf are established very early in the ontogeny of the leaf, certainly at the time cell division ceases, when the leaf is about one-tenth of its final size, and probably much earlier, while cell division is still going on. An example of the evidence for this assertion is given in Fig. 2.

At this point attention was turned to the relation between height of insertion on the shoot and leaf shape. Some strains of *Ipomœa cærulea* produce entire leaves at the first few nodes, and

subsequent leaves are more and more deeply lobed. Lateral shoots from upper nodes of such strains carry only lobed leaves ; lateral shoots from lower nodes carry leaves which repeat (in whole or in part) the transition from entire to lobed leaf which is typical of leaves on the main shoot. It is a study of this phenomenon, particularly in the cotton plant, which led Krenke (1933–35) to propose the hypothesis that there are cycles of ageing and rejuvenation in plants which can be recognised from changes in leaf shape ; that every lateral branch is " physiologically younger " than the node from which it arises ; and that treatments which hasten or
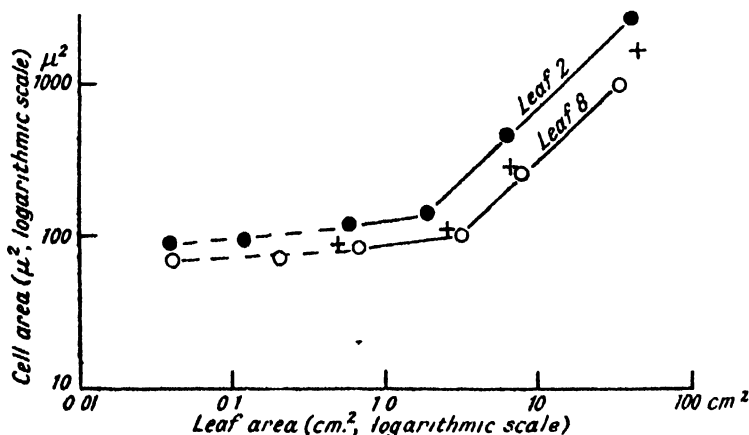
Fig. 2.—Relation between leaf area and cell area in 2nd, 5th and 8th leaves of *Ipomœa cærulea* at different stages of maturity.

Ordinates, log cell area (μ^2), abscissae, log leaf area (cm ^{2}) ; unbroken lines join points obtained from observations made on leaves sampled at known areas, broken lines join points obtained from observations made on leaves dissected from apices ; ●, 2nd leaves, +, 5th leaves, O, 8th leaves.

(*By courtesy of the Editor of the " New Phytologist " and the Cambridge University Press*)

delay maturity also hasten or delay the familiar transition from simple to complex leaf-shapes. *Ipomœa cærulea* is a plant which flowers prematurely in short days : therefore it is suitable material on which to test the validity of Krenke's hypothesis.

Experiments were carried out (Ashby, in press) in which batches of *Ipomœa* were grown in two different lengths of day, namely 8 hours and 16 hours, but were otherwise kept in as uniform conditions as possible in a heated glasshouse. In 8-hour days flower buds appeared even at the first node, in two or three weeks. In 16-hour days flower buds did not appear for several weeks, and then only from nodes above the fifteenth. There was therefore a striking difference in rate of development of the two batches of *Ipomœa*. Accompanying this difference there was a difference in leaf shape : in 16-hour

days the familiar transition from entire to lobed leaves began at the fifth leaf; in 8-hour days lobing was almost completely suppressed. The conclusion from these experiments is that leaf shape is indeed sensitive to treatments which hasten or delay physiological ageing, but the correlation between ageing and leaf shape is not as simple as Krenke supposed. There is some evidence which suggests that the shapes of leaves on lateral shoots depend on the time they are differentiated: if, for instance, a second leaf on a lateral is differentiated at the same time as an eighth leaf on the main axis then these two leaves have the same shape. This suggestion needs confirmation; if it is correct it is a striking example of the control of pattern all over the plant by internal factors. Furthermore the experiments support the view that these internal factors are growth hormones, for if plants growing in 8-hour days are exposed also to periods of one hour of light (at no more than 18 foot-candles) in the middle of the night, then the premature flowering associated with 8-hour days is prevented, and the leaves produce lobes as though they were growing in 16-hour days.

The results of experiments on the responses of flowering and leaf shape in *Ipomœa* to day length vary according to light intensity and temperature. Therefore it is clear that the responses are too complex to be analysed unless the environment is more precisely controlled. Accordingly attention was turned to *Lemna minor* which can be grown under closely controlled conditions, and in which the study of ageing can be dissociated from the complexities of flowering and morphological development which accompany ageing in *Ipomœa*. Preliminary experiments (Ashby, Wangermann and Winter, 1949) disclosed that individual fronds in a colony of *Lemna* growing exponentially are not immortal. They have a limited length of life and, in a constant environment, they produce a characteristic number of daughter fronds at characteristic intervals. Even though successive daughter fronds come from the same meristem and develop in the same environment, no two of them are alike Each daughter frond is smaller than the one preceding it because it consists of fewer cells; moreover, each has a shorter life and produces in turn fewer daughters than the frond preceding it. There are, therefore, between the successive fronds from one meristem in *Lemna minor*, even more striking differences than occur between successive leaves on the shoot of a land plant. A thorough investigation has recently been made of the relation between the length of life of a *Lemna* frond under different conditions and the rate of diminution of area between its successive daughter fronds (Wangermann and Ashby, 1950). It is possible to change the length

of life of a frond by various treatments, and in every instance in which this has been done a change in length of life of a " mother frond " is accompanied by a corresponding change in the rate of diminution in area of its successive daughter fronds. An example of this is given in Fig. 3.

The experiments provide convincing evidence that in *Lemna* a distinction can be drawn between the " time age " and the " physiological age " of a frond. Two fronds grown at different temperatures, or an early and a late frond from the same mother,
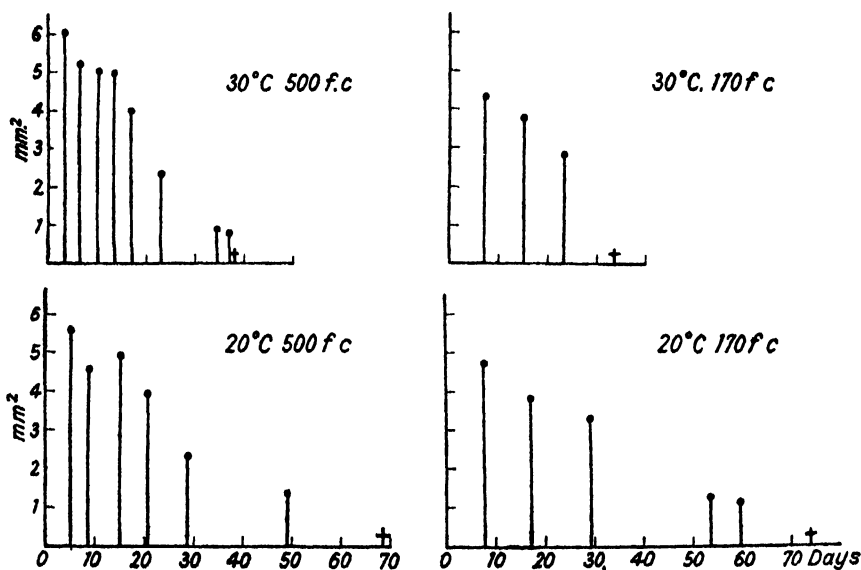
Fig. 3 —Relation between area of su⌣
    of mother frond at which daughters appeared (abscissæ), for mother fronds
    growing in four different conditions.
    † represents time of death of mother fronds.
    (WANGERMANN, 1950.)

may all be the same " time age " but nevertheless have different expectations of life ; and the relative areas of their daughter fronds provide a simple criterion for the comparison of their physiological

There is an apparent contradiction between the fact that even under constant conditions successive daughter fronds diminish in area, and the fact that the mean frond area of a colony remains constant. This apparent contradiction is resolved by a third fact, namely that the first daughter fronds of subnormally small fronds (*i.e.* fronds from old mother fronds) undergo a process of rejuvenation :

they are larger than the fronds which gave rise to them. And this increase in area recurs in subsequent vegetative generations of first daughter fronds until the maximal area is restored. In brief, the exponential growth of a colony of *Lemna minor* can be resolved into cycles of ageing and rejuvenation in individual fronds and their vegetative progeny.

Some progress has been made in an analysis of the factors which determine frond size in *Lemna minor*. There is reason to suppose (Wangermann, 1950) that a frond produces a growth promoting substance which diminishes in quantity, or activity, as the frond becomes older. The length of life of the frond depends upon the initial amount of the substance and its rate of diminution. The substance diminishes more rapidly in the presence of heteroauxin (2 5 mg./litre) ; also it diminishes more rapidly at high temperatures than at low temperatures (the temperature coefficient of the rate of diminution is about 2). Its activity is independent of light intensity between 170 and 500 foot-candles. A daughter frond does not expand to its full area unless it has at least a fragment of the mother frond attached to it ; this is interpreted to mean that the growth promoting substance is passed from mother to daughter, and the area reached by a daughter frond depends on the quantity, or activity, of the growth promoting substance it receives from its mother at the time it is differentiating. If these conclusions are confirmed, they are evidence for the existence of a growth hormone which controls expectation of life and rate of ageing in *Lemna minor*, and the next step in the investigation is to describe the physiological properties of the growth hormone and to attempt to identify it.

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RECENT ADVANCES IN SCIENCE

ASTRONOMY. By Michael W Ovenden, B.Sc , F.R A.S., University Observatories, Cambridge.

The Origin of Comets.—Historically, the appearance of a bright comet has always been taken, by the uninitiated, as an omen of good or evil. The relatively rare, and frequently unpredictable, occurrence of such strange and striking objects would naturally be met with wonder and awe. To the modern astrophysicist, with his wider horizons of metagalactic space, even a great comet may seem a relatively unimportant part of the cosmos, a matter for interest but hardly for awe. But, while to him a comet may no longer hold any awe-inspiring quality, it nevertheless retains something of the mystery, and, while objectively of little present influence in either the solar system or the general scheme of the universe, the origin of comets may well hold a significant key to the still unsolved problem of the origin of the solar system. It is with this prospect in view that a theoretical model has been sought for the general system of comets which would be capable of explaining, not only the general physical characteristics of the various types of comet, but also the characteristics and distribution of elements of the cometary orbits. The problem of the origin of comets has indeed exercised the minds of many a great astronomer in the past, but it is only with the recent publication of a new comprehensive theory by Oort that an approach to a satisfactory definitive theory can be said to have been made (*B.A.N.*, **11**, 91, Jan. 1950).

The increasing light-gathering power of astronomical telescopes has shown that comets are not, in fact, particularly rare objects. No year goes by without the discovery of a number of new comets, many of which prove to have elliptical orbits with periods which can be measured in years or decades. In the past this increased light-gathering power has been obtained at the expense of very restricted fields, but the development in recent years of the Schmidt cameras with wide fields has enabled a much more complete coverage of the sky to be made. In the future it is more likely to be the Schmidt cameras which make the greatest additions to the list of

known comets than, as in the past, the assiduous amateur observer with a modest telescope but a detailed knowledge of the sky.

It is highly significant that, of the new discoveries of faint comets, most prove to have orbits of short period, while the bright comets with well-developed coma and tail have periods which must be measured in hundreds or thousands of years. A comet develops a tail by the action of solar radiation pressure on occluded gases released from its head by the heat of the Sun, and it thus develops a tail only when within that small part of its orbit lying close to the Sun. The short-period comets, never travelling far from the Sun and making frequent passages through perihelion, would in a cosmically short time lose all their occluded gases, and remain only as faint nuclei. This process of dissipation is not the only one which contributes to the continual decrease in the number of bright long-period comets, for the perturbing action of the planets renders an originally long-period orbit into either a short-period one, or into a hyperbolic one, the comet in the latter case being lost to the solar system. To explain the present occurrence of bright long-period comets in a solar system whose age is measured in thousands of millions of years is, indeed, one of the major problems which any theory of the origin of comets has to solve.

The early theories fall into two distinct groups, the one supposing that the comets originate in the solar system by a process which must be continuously active, the other supposing that comets exist in interstellar space, their rate of occurrence thus bearing no relationship to the age of the solar system. More than a century ago, Laplace (*Œuvres Complètes*, **13**, 88, 1904) examined the consequences of the interstellar hypothesis. In order to predict the observable properties of the distribution of orbital elements of comets, some assumption must be made about the distribution of velocities in the interstellar field of comets. He introduced two conceptions, namely the sphere of action of the Sun, a sphere with the Sun as centre and radius of 10^5 astronomical units, outside which the influence of the Sun could be neglected, and the sphere of visibility of radius 2 astronomical units, outside which the comet would be invisible from the Earth; with present techniques this radius should probably be nearer to 4 astronomical units. Laplace assumed that, outside the sphere of action, the number of comets with space velocities between v and $v + dv =$ constant with all velocities from 0 to ∞. With this distribution, he found that the number of elliptic and parabolic comets entering the sphere of visibility must far surpass the number of hyperbolic comets. This is indeed one of the most significant features of the cometary orbits,

for in all cases where a definitely hyperbolic orbit has been established, an examination of the previous path has led to the belief that the orbit was originally parabolic or elliptical, and thrown into an hyperbola by planetary perturbations. Such a velocity distribution is, however, highly artificial, having a singularity for $v = 0$. When a more reasonable distribution is adopted, and further account taken of the relative velocity of the Sun and the interstellar cometary field, the whole picture alters, and a large excess of hyperbolic orbits should occur, in obvious contradiction to observation.

This difficulty seems insurmountable, and recently attention has turned to variations of the scheme originally suggested by Lagrange (*Additions à la Conn. du Temps pour 1814*), which supposed that comets originate from explosions on one of the major planets, a process supposed to be continuously operating. In support of this view, it can be shown that a number of comets, if their orbits are traced back, allowing for planetary perturbations, do appear to coincide, within the errors of observation and calculation, with Jupiter. The existence of a " family " of comets related to Jupiter (and less-distinct families related to Saturn and Uranus) is a marked characteristic of observed short-period orbits, but it would not seem possible in this way to account for more than a very small fraction of the total number of comets recorded.

It is clear that a real difference does exist between the distribution of orbits of short- and long-period comets. The short-period comets show some preference for the plane of the ecliptic, for direct motion and for relationships with the major planets. The long-period comets show no such preferences. Indeed, at first sight the high proportion of orbits with high inclinations might suggest an avoidance of the ecliptic plane (*see*, for example, H. W. Wood, *J. Brit. Astr. Ass.*, **60**, 105, March 1950). However, a random distribution of orbital planes can be represented by a random distribution of orbital poles; then such a random distribution with a homogeneous density of poles over the whole celestial sphere would result in a maximum number with poles in the ecliptic itself, *i.e.* a maximum number with high inclinations. (The same is true, of course, for inclinations measured from any great circle plane.) The number of long-period comets whose orbits are sufficiently well-known is small, but there is slight evidence that there are fewer with high inclinations than a purely random distribution would indicate, and hence some very slight preference for the ecliptic with long-period comets is indicated, but it is much less pronounced than for the short-period comets, and any tenable theory must account for this difference.

In 1948, A. J. J. van Woerkom made an important contribution to the theoretical approach by examining the detailed effects of perturbations by the major planets, in particular Jupiter, on parabolic orbits (*B.A.N.*, **10**, 445), and showed conclusively that on the average such orbits would be altered either to short-period orbits which thus become temporary members of the Jovian family, or to hyperbolic orbits, the comets thus being lost to the solar system. With van Woerkom's theoretical results as a basis, Oort examined the observational data to try and explain why long-period comets are still observed while yet not coming from any interstellar field. The reduction of a definitive orbit for a long-period comet from observation is difficult since the comet can only be observed over the very small arc of its orbit in which it is in the sphere of visibility, and the nature of a comet is not such as to make accurate positional measurements easy. In many cases, it is not possible to distinguish between an ellipse, a parabola and an hyperbola if the period is greater than 1000 years. However, in 1914 E. Strömgren developed a technique of analysis which enables definitive orbits of some score of very long-period comets to be obtained. The distribution of orbits so revealed is remarkable in that, although no hyperbolic orbits occur, there is a very sharp frequency maximum for orbits whose semi-major axes lie between 50,000 and 150,000 astronomical units.

Oort therefore supposed that at such distances lies a cloud of comets from which the long-period comets come. This distance is an appreciable fraction of the distance to the nearest star, and Oort examines the effects of perturbations by stars on orbits reaching out to 10^6 astronomical units. It is this consideration of stellar perturbations which is the significant and novel contribution which Oort has made to theory. He finds that for orbits with aphelia greater than 2×10^5 astronomical units, stellar perturbations will cause ejections from the solar system within relatively short periods of time. Here then is the explanation of the upper limit to the radius of the cometary cloud, and also to the period of observed comets, since for a member of the cloud to be able to enter the sphere of visibility its orbital eccentricity must lie within fairly close limits.

For comets whose aphelion distance is less than 2×10^5 astronomical units, the orbits will be relatively stable as far as stellar perturbations are concerned, but those whose eccentricities are great enough will have entered the region of the planets and been transformed into either short-period comets or hyperbolic ones. In order to account for the " new " long-period comets, Oort examines the second-order effects of stellar perturbations, and finds that they are

able to make significant changes, since a comet with a highly eccentric orbit will spend most of its period near aphelion. In fact, they are sufficient to render the distribution in orbital planes and perihelia quite random, all components of velocity being equally distributed before the comet has time to reach the sphere of visibility. In order to explain the number of " new " comets observed, it is only necessary to postulate a sufficiently large number of comets within the cloud ; the number so deduced is of the order of 10^{11}. The process will continue until an appreciable fraction of the total number of comets have been " diffused " from the cloud, and it is proved that, at the present age of the solar system, the depletion in this way is negligible. Once this mechanism is assumed, the perturbations by Jupiter examined by van Woerkom are able to explain the formation of the short-period comets and the characteristics of their orbits. The theoretical distribution of semi-major axes derived from this hypothesis agrees well with observation, except for a slight excess of " new " comets, a discrepancy which Oort believes due to the greater tendency of a comet approaching the sun for the first time to develop an extensive luminous envelope, and hence to be more easily observed.

In seeking an explanation for the existence of this cloud of comets, Oort begins with the relationship between comets and other bodies of the solar system. On the one hand, the close connection between the orbits of some meteor streams and comets suggests at least a common origin for the two types of body. On the other hand, the extension of the number of minor planets known has shown that the difference between the orbits of these bodies and short-period comets is not so distinct as was at one time believed (see SCIENCE PROGRESS, 38, 476, July 1950). Further evidence for the connection comes from the examination of the physical structure of the cometary nuclei. The fact that a comet with a small perihelion distance traversing the solar corona remains intact indicates that the size of the component units of the nucleus cannot be less than about half a kilometre, although to account for the transparency and low density of the comet they must be separated by relatively large distances ; such particles would form a " missing link " between the larger meteors and the smaller asteroids. If a common origin for both meteors and comets is assumed, then comets cannot have been formed by the process of gradual condensation and accretion (such as was suggested by Lyttelton, *Mon. Not. Roy. Astr. Soc.*, 108, 465, 1948), since the complex internal structure of meteorites can only be explained by formation at a temperature much higher than that of interstellar or interplanetary space. The minor planets

have generally been supposed to have originated in the disruption of a planet which originally pursued an orbit between Mars and Jupiter. Oort suggests that those fragments of the explosion which had, or were soon thrown into, circular orbits became stable and constitute the main belt of minor planets. Others with elliptical orbits rapidly suffered large perturbations by the planets, and van Woerkom's analysis shows that the effect of this would be for all but 3 per cent. of the fragments to be rapidly dispersed to interstellar space. The remaining fragments would form the cloud of comets postulated by Oort. Such fragments would be able to retain occluded gases until due to stellar perturbations they again entered the sphere of visibility as comets, but with orbits sufficiently perturbed for no evidence of an origin at a single point of space to remain.

It is possible, in a rather inexact way, to make a test of Oort's hypotheses. If it is assumed that the original exploding planet had a mass lying somewhere between that of Mars and Jupiter, and that 3 per cent. of this mass now remains in the solar system as a cometary cloud, the number of comets in the cloud being about 10^{11} (as deduced from the number of comets observed) then the mass of each comet must be of the order of 10^{16} grams. It is not possible to estimate the mass of a comet directly, an upper limit of perhaps 10^{20} grams being all that could be stated. From indirect evidence, Vorontsev-Velyaminov deduced that the mass of Halley's comet was of the order of 10^{19} grams (*Astrophys. J.*, Sept. 1946). Considering the uncertainties of both the theoretical deductions and the observational data, the agreement is quite satisfactory.

Oort has for the first time produced a comprehensive theory which is consistent with our knowledge of the physical constitution of comets and their relationship with minor planets and meteors, and which gives a semi-quantitative explanation of the main features of the distribution of orbital elements in both the short- and long-period groups. It rests fundamentally upon the assumption of a cloud of comets situated at distances between 50,000 and 150,000 astronomical units, and if the work of Strömgren on the distribution of semi-major axes of the score of long-period comets which are all that have been sufficiently accurately observed hitherto can be taken as representative of the complete group, then the hypothesis can be said to be at least partially confirmed by direct observation. It remains to be proved whether or not the explosion theory, combined with planetary perturbations, is able to explain the individual cases of peculiar orbits, such as that of the recently discovered asteroid of smallest known mean distance (*see* SCIENCE PROGRESS, **38**, 475, 1950).

The comets which are thrown into hyperbolic orbits and are lost to the solar system will form an interstellar field of comets. It is interesting to speculate whether other planetary systems are also contributing to this field. If it is assumed that all stars have planetary systems producing hyperbolic comets at the same rate as that of the Sun, there would be a density of about 10^{12} comets per cubic parsec. The general distribution of velocities would be the same as that of the parent stars, and Jeans' classical formulæ on stellar encounters enable the prediction to be made that a truly hyperbolic interstellar comet should enter the solar system about once every century. With our present almost complete ignorance of the mechanisms involved in planetary formation it is impossible to say how poor an assumption is the one that supposes all stars to have a planetary system, and furthermore it by no means follows that in every possible planetary system an exploding planet will occur, but the possibility of observing a truly hyperbolic comet in the future would not appear too remote. If such is observed, any differences in its physical constitution may give valuable clues to the processes involved in the formation of planetary systems.

PHYSICS. By Professor F. A. Vick, O.B.E., Ph.D., F.Inst.P. University College of North Staffordshire.

Optical and Electron Microscopes.—1.—Not so very long ago it appeared to the non-specialist as if the development of the optical microscope was reaching its limit, except for details of design, but that, on the other hand, the electron microscope might be improved considerably in performance. During recent years, however, there have been exciting additions to the scope of the optical microscope by, for example, the use of phase contrast, aspherical surfaces, mirrors instead of lenses, etc. The electron microscope, in what is becoming the conventional design, appears to be reaching a resolving limit of about 5 A., and there seems to be little prospect of improving this appreciably by standard techniques and improvements in precision of construction. Here again, fortunately, new principles are now being applied to extend the usefulness of the instrument. It is the purpose of this article to indicate some of the newer developments in both electron and optical microscopy, and to compare and contrast the scope and limitations of the instruments.

2.—In a brief but interesting paper (*J. Opt. Soc. Amer.*, **40, 269**, May 1950) L. Marton has made a general comparison of the uses of electrons and photons in microscopes. The charge of the electrons means that repulsive forces between them must be taken into

account. Both the energy and momentum of electrons are continuously and arbitrarily variable. The refractive indices of media for photons vary between 1 and 2, while the equivalent refractive index in electron optics is again continuously variable over a range of 1000 : 1. Inelastic scattering of electrons by atoms of the object through which they pass is very important, especially if the atoms are of low atomic number. An electron microscope must be operated in a good vacuum, which imposes severe limitations on the specimens which may be used as objects. Nowadays, electron microscopes often have three stages of magnification instead of the two normally used in light microscopes (*e.g.* M. E. Haine, R. S. Page and R. G. Garfitt, *J. Appl. Phys.*, **21**, 173, Feb. 1950). The lenses are focused electrically and not by mechanical movement, except in a few cases.

The wavelength of electrons is of the order of 10^5 smaller than that of the photons used in ordinary microscopes, and one would expect, therefore, a correspondingly smaller resolving limit. In practice, the aberrations of electron lenses make necessary the restriction of their numerical aperture to about one-thousandth of the best achieved in light microscopes, so that the least resolved distance for an electron microscope is about 5 A. (compared with about 4000 A. for U.V.). Experimentally, a resolving limit of about 10–15 A. is reached in modern electron microscopes. To achieve this, the mechanical tolerances in machining the components of electron lenses are very fine. On the whole, the ranges of usefulness of electron and light microscopes do not overlap. There has, however, been continuous interchange between the developments of the two types of microscope, and each continues to influence the other.

3.—This is not the place to discuss the technical advances in the detailed design and use of electron microscopes ; they have been described in a number of books and review articles as well as in original papers (*e.g.* R. A. Scott, SCIENCE PROGRESS, **35**, 638, 1947 ; L. Marton, *Phys. Soc. Progr. Report.*, **10**, 204, 1945 ; D. Gabor, *The Electron Microscope* ; V. E. Cosslett, *The Electron Microscope* ; Ed. D. G. Drummond, *The Practice of Electron Microscopy* ; R. W. G. Wyckoff, *Electron Microscopy : Technique and Applications*). There have been some very interesting new methods suggested during the last few years. The first is now well-known and widely used and consists of the evaporation in a high vacuum of metal atoms (*e.g.* gold) at an angle on to the specimen, so as to cast " shadows " which increase the contrast in the image by electron transmission (R. D. Williams and R. W. G. Wyckoff, *J. Appl. Phys.*, **17**, 23, 1946). The second is the electron-optical analogy of the

schlieren effect (L. Marton and S. H. Lachenbruch, *J. Appl. Phys.*, **20**, 1171, 1949). In principle, the effect is observed by projecting the image of an electron source on to an axial stop by means of an electron lens or lens system. The stop blocks all the direct rays, and in the absence of any scattering object or deflecting field in the space between source and lens there is no electron beam beyond the stop. If, however, there is between source and lens scattering material or a magnetic or electric field which varies " the refractive index for electrons " the rays will be deflected from their normal paths and will form a dark-field image in the space beyond the stop and this can be photographed or observed on a fluorescent screen. The image on the plate or screen is thus a pictorial representation of the deflections in a plane conjugate to the image plane with respect to the lens.

In their first experiments, the authors used a length of cobalt-nickel-plated brass recording wire, 0·117 mm. diameter, magnetised by short current pulses spaced at about 0·43 mm. distance and alternating in sign. The wire thus has a series of magnetised portions of equal strength, size and separation and with neighbouring poles alike. The field distribution in the neighbourhood of the wire was checked by a powder pattern (using a ferromagnetic colloid) and then the wire placed in the object space of an electron microscope, perpendicular to the axis of the lens. The centre stop at the lens focus consisted of a 1-mm. copper disc supported by two fine metallic crosswires. A fluorescent screen was used to observe the image. The electron beam passing near the wire was devia.ed by the magnetic field, and gave a schlieren picture as in Fig. 1.

Shadow of wire
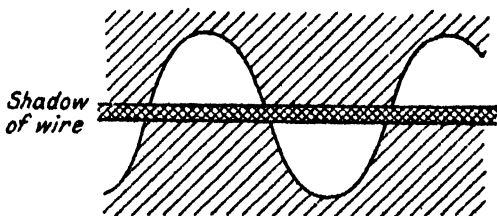
Fig. 1.

The bright schlieren images were easily identified with the magnetic field regions by comparison with the powder patterns. While quantitative measurements of field strength are possible in principle from such schlieren photographs, they would be difficult in practice. Dr. Marton and his colleagues have, therefore, modified the method to give a bright-field shadow, which makes quantitative work easier.

In the bright-field method, the obstruction is moved from the

axis in a plane parallel to that of the lens. In the absence of dis-
turbing fields, a pencil of electrons passing through the lens will
cast a sharp shadow of the obstruction on a screen or plate in the
image plane. A disturbing field will then cause this shadow to
move by an amount depending on the strength and geometry of
the field. The displacements of the shadow thus enable the pro-
perties of the field to be determined. If, for example, the disturbing
field is produced by the magnetised wire already described, and the
obstruction is a parallel (unmagnetised) wire, the shadow of the
latter consists of a series of loops corresponding to the periodic
magnetic field round the first wire. The authors have found that
experimental values of the deflections of shadows inserted into
theoretical formulæ which they derive give results verifying the
theory and consistent with independent measurement.

The paper is important in that it shows that electromagnetic
fields may be added to the " objects " studied in the electron
microscope.

4.—A most ingenious method of increasing the effective resolving
power of the electron microscope has been described by D. Gabor
(*Nature*, **161**, 777, 1948 ; *Proc. Roy. Soc.*, **A197**, 454, 1949), which
makes use of reconstructed wave fronts. In principle, the object
is illuminated by a coherent monochromatic electron beam brought
to a fine focus just before or just after the object. The emergent
secondary wave front falls on a photographic plate some distance
away. Though the arrangement superficially resembles a shadow
microscope, the phootgraphic record is quite different, being pro-
duced by interference between the background and the coherent
parts of the secondary wavelets from the object. The photograph
is then printed (or developed by reversal). If it is now illuminated
with a coherent monochromatic *light* beam which reproduces all the
characteristics of the electron beam (including aberrations produced
by the lenses) and if the relative position of the plate is the same as
before, scaled up in the ratio of the wavelengths (*i.e.* about 100,000),
then there is synthesised an enlarged image, of the original object,
which can be focused by a suitable lens on to a second photographic
plate. In order to avoid scaling up the linear dimensions in practice,
a further lens is introduced with focal length equal to the distance of
the object from the first photographic plate in the electron case,
and so placed as to produce a reconstructed image practically at
infinity. The arrangement is sketched in Fig. 2 (based on Fig. 1
of Dr. Gabor's paper by kind permission of the author and of the
Royal Society).

Provided that the aberrations of the electron lenses can be

reproduced in the optical synthesiser, it is no longer necessary to push to the limit the correction of the electron lenses, or to use extremely small numerical apertures. The technical difficulties are still large, but not impossibly so, and Dr. Gabor estimates that a resolution limit of 1 A. could be achieved. So far, the principle has been tried out optically only (*i.e.* by using monochromatic light instead of an electron beam), and the results are very promising. One most valuable feature is that the diffraction photographs contain data for the reconstruction of three-dimensional images. One plane after another of extended objects can be observed in the optical part of the microscope, just as though the original object (enlarged)
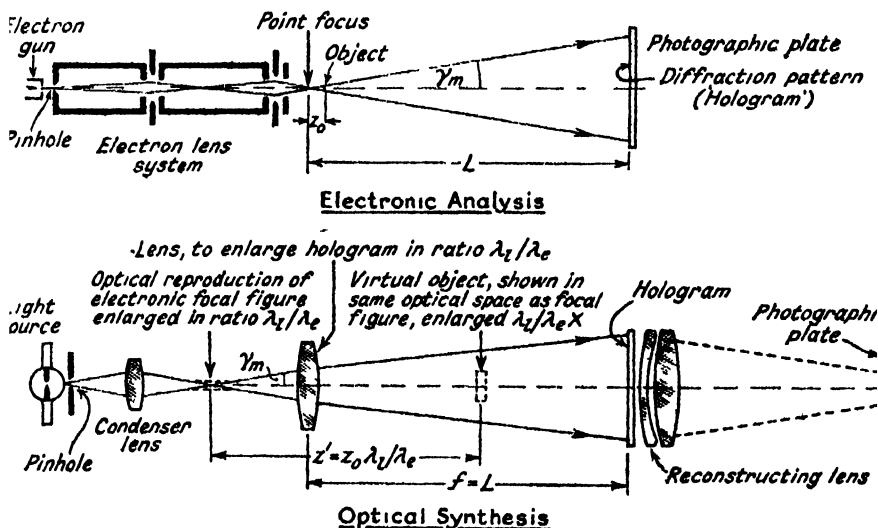
Fig. 2.

were in position. Experiments are now in progress on both sections of the device, and the results will be awaited with interest. For the theory of wave-front reconstruction the *Proc. Roy. Soc.* paper should be consulted.

5.—Turning now to optical microscopes, the expanding use of phase contrast is now well-known and need not be enlarged upon here. It is of interest to note, however, that the method is now used for viewing opaque objects by vertical illumination (H. Jupnick, H. Osterberg and G. E. Pride, *J. Opt. Soc. Amer.*, **38**, 338, 1948).

Among other recent developments have been the use of reflecting surfaces, both spherical and aspherical. The painstaking and enthusiastic work of C. R. Burch has been the admiration of many of us, and in two short papers (*Proc. Phys. Soc.*, **59**, 41 and 47, 1947)

he discusses reflecting microscopes made by him, based on some fundamental work by Schwarzschild as long ago as 1905. The reflecting objectives consist of a concave mirror with a central hole facing a smaller convex mirror. Sometimes both mirrors are aspherised, and sometimes the convex mirror is spherical. Figures quoted by Dr. Burch for two objectives include N.A. = 0·58, mag. = × 47 ; N.A. = 0·65, mag. = ×100 respectively. The visual performance of both objectives was comparable with good refracting objectives of equal N.A. One great advantage of such an objective is that it can be used directly with U.V. after focusing in visual light (the photographic plate being placed at the primary image).

A quite different kind of U.V. microscope has been described by B. K. Johnson (*J. Sci. Instr.*, **26**, 148, 1949), in which the first magnification is produced by reflection from the silvered back surface of a lithium fluoride meniscus lens (rather similar to a mangin mirror), followed by fused quartz lenses and a Ramsden-type eye-piece corrected for U.V. It was found possible to reduce the chromatic aberrations to zero for a U.V. wavelength in the neigh-bourhood of 2750 A. and also for visible green light about 5460 A., so that the microscope may be focused in the latter wavelength and used in the former. The N.A. for 2740 A. is 1·27 if the lens system is immersed to the object in a glycerine-water-sugar solution ; and 0·58 without any immersion.

Another microscope using reflecting surfaces has been described by J. Dyson (*Proc. Phys. Soc.*, **62B**, 565, 1949) This instrument is intended to fill the need for a microscope with a long working distance. This is often required in, for example, the examination of the surfaces of metals at high temperatures, surfaces inside vacuum tubes, biological specimens in water, etc. Effectively, the first objective is of unit magnification and consists of a spherical concave mirror so placed that the object is almost at the centre of curvature. Between object and mirror is a half-silvered plate which forms an image just behind the concave mirror, which is perforated with an axial hole to enable the image to be examined by an ordinary microscope objective. For vertical illumination, a thin half-silvered pellick mirror, made from collodion stretched across a ring which has been ground flat, is placed at 45° between the back of the concave mirror and the main microscope objective. To reduce spherical aberrations, the side of the first half-silvered mirror nearest the object may be worked to a weak convex surface. Dyson has described modifications of the objective for examining nuclear plates and for immersing in water for the observation of biological specimens.

R. Kingslake and P. F. DePaolis have described briefly (*Nature*, **163**, 412, 1949) some of the remarkable new glasses developed during the last twenty years in the Kodak laboratories. These increase considerably the ranges of refractive indices and dispersive powers available to the lens designers. Although the stimulus for the development of the glasses came largely from the camera industry, there should be corresponding advantages in the design of microscope lenses.

GENERAL AND PHYSICAL CHEMISTRY. By J. W. SMITH, D.Sc., Ph D., F.R.I C., Bedford College, London.

CLATHRATE COMPOUNDS.—Mention has been made previously (SCIENCE PROGRESS, 1948, **36**, 664) of the peculiar addition compounds of the general formula $3C_6H_4(OH)_2,M$ which are formed by quinol. These are produced by allowing quinol to crystallise from a solvent in the presence of a high concentration of the compound M. Under these conditions the quinol may separate in a hydrogen-bonded cage form, now termed β-quinol, in which two interpenetrating giant molecules of the hydrogen-bonded quinol units can enclose molecules of M to give the addition products. Since the report referred to above the addition of other molecules to quinol has been observed, and compounds are now known in which M may comprise H_2S, SO_2, CH_3OH, CH_3CN, $H.CO_2H$, CO_2, HCl, HBr, C_2H_2, or even an atom of one of the inert gases argon, krypton, or xenon (Palin and Powell, *J. Chem. Soc.*, 1948, 815 ; Powell, *ibid.*, 1950, 298, 300, 468).

As a result of these studies it has been found that the enclosed molecule must satisfy certain requirements of size and shape. Naturally it must not be too large for the space available in the cavity, but certain minor modifications of shape may occur in the quinol framework to accommodate different molecules. With a small and effectively spherical molecule such as hydrogen chloride, which does not fill the cavity completely, the two interpenetrating quinol frameworks which form the walls of the enclosing cavities adjust themselves to the positions they would occupy in the absence of any enclosed component, but to include non-spherical molecules the quinol structure distends like a trellis, being extended along the c axis of the hexagonal lattice and contracted in directions at right angles to this axis. These modifications in the shape of the lattice have been correlated with the dimensions of the enclosed molecules. A very slight distension only occurs when the methyl alcohol molecule is enclosed, but with a much larger molecule, such

as that of methyl cyanide, the distortion of the lattice is considerable, and the included molecule orients itself so as to fit into the surrounding structure. These modifications in the shape of the crystal lattice are in accord with the weak optical birefringence observed with these products. The double refraction for the compounds with hydrogen chloride, hydrogen bromide, hydrogen sulphide, acetylene, and methyl alcohol is slightly negative, whereas that for the compounds with formic acid, sulphur dioxide, and methyl cyanide is slightly positive, the highest value being found for the compound with methyl cyanide, which has the most distended structure.

The latest and most interesting additions of all to this series of products are those in which the included molecules are inert gas atoms. The van der Waals radius for a methyl group in crystals is about 2 A., so it is to be expected that spherical atoms of this size and somewhat larger would be enclosed and retained by the cages. In the solid state the radii of the inert gas atoms are neon 1·61, argon 1·9, krypton 2·0, and xenon 2·2 A. The radii at room temperature will be rather greater than those values. It was to be expected, therefore, that addition compounds with argon, krypton, and xenon might be possible. This prediction has now been confirmed, and these inert gases have for the first time been converted into forms which bear some resemblance at least to a stable combined state.

The technique for the preparation of these compounds is extremely simple. About 30 c.c. of an aqueous solution of quinol, saturated at room temperature, is placed in a stainless steel pressure vessel, together with a further quantity of quinol such that it will dissolve when the solution is heated. After washing out atmospheric gases, the inert gas is introduced under pressure, and the pressure vessel is heated in a large water bath. The solution is then allowed to crystallise by slow cooling.

There is no strong interaction between the quinol and the inert gas, and so there is no spontaneous tendency for the latter to be included in the crystal, such as might be assumed for polar compounds like hydrogen sulphide and sulphur dioxide. It is therefore necessary to arrange matters so that an inert gas atom is available in position at the surface of the growing crystal whenever a cage of quinol molecules links up. As the solubilities of the gases in water are low this can be assured only by using a fairly high pressure. In Powell's work the gas pressures used were 40, 20, and 14 atmospheres for argon, krypton, and xenon respectively. As the solubilities of these gases increase with increasing atomic weight

these conditions lead to approximately equal inert gas concentrations, so that when the crystals of the β-form had been separated from the α-quinol which had separated out at the same time they were found to have compositions corresponding to $3C_6H_4(OH)_2,0\cdot8A$, $3C_6H_4(OH)_2,0\cdot74Kr$, and $3C_6H_4(OH)_2,0\cdot88Xe$, respectively. This indicates that about 80, 74, and 88 per cent., respectively, of the available " holes " in the β-quinol structures are occupied by the inert gas atoms. It seems likely, therefore, that if still higher gas pressures could be used almost complete occupation of the available holes might be achieved in the cases of the more soluble krypton and xenon.

X-ray studies have shown that in these inert gas addition compounds the quinol has the undistended structure which would be expected from the spherical form of the included molecule. The argon compound undergoes no visible change on keeping at room temperature for some weeks. It gives off gas only very slowly at 40° C., but more rapidly at higher temperatures. It has, of course, no equilibrium vapour pressure, as the process concerned is irreversible, there being no tendency for gaseous argon to be taken up by solid quinol. On the addition of a solvent such as methyl alcohol to dissolve the quinol the inert gas is evolved vigorously.

It has been suggested by Powell that, under suitable conditions, these compounds might prove to be a convenient portable source of the inert gases. Other similar addition products of these gases might also be envisaged, but preliminary attempts by Powell to form clathrate compounds of argon with resorcinol, p-aminophenol, or p-phenylene diamine from ethyl alcohol solution have so far proved unsuccessful.

Quinol and helium also have given no addition product from benzene solution, but this result was to be expected, owing to the small effective size of the helium atom, well known for its power of penetrating small spaces, with the result that it cannot be retained by the quinol cage formed by six oxygen atoms linked through hydrogen bonds of length 2·75 A. along the sides of a plane hexagon. So far the addition of neon does not appear to have been investigated, but it will be interesting to see whether this atom, also, is able to slip out of the quinol cage.

" ADDUCTS " OF CARBON-CHAIN COMPOUNDS WITH UREA.—Over thirty years ago it was observed by Wieland and Sorge that some of the choleic acids formed addition products with paraffins and with fatty acids in which the proportions of the components depends on the chain length of the second constituent. The two components, however, are always present in a simple molecular ratio of 1 : 3,

1 : 4, 1 : 6, or 1 : 8. The compounds, however, all appear to be built on the same basic lattice, as Go and Kratky (*Z. physikal. Chem.* 1934, **B26,** 439) found that almost all the deoxycholic acid–fatty acid compounds which they studied gave the same X-ray diagram. The chain molecules must therefore be enclosed in some manner which results in their not being detectable by X-ray methods, and Go and Kratky suggested that the fatty acid molecules are arranged one behind another, forming canals extending through the basic lattice.

A more extreme case of behaviour of this kind has been observed by Bengen (*cf.* Bengen and Schlenk jr., *Experientia*, 1949, **5,** 200), who found that urea has the property of combining with some paraffin hydrocarbons and with certain types of oxygen-containing aliphatic compounds to form crystalline addition products. These bear some similarity to clathrate compounds in that the presence of the second constituent induces the urea to crystallise in a form differing from its normal structure, so as to permit it to include molecules of the chain compounds, but they differ from the clathrate compounds in that the included molecules are not trapped completely within the crystal lattice of the urea. They differ, too, from the choleic acid addition products in that, whilst the molecular ratio of the constituents changes with the chain length of the second component, this ratio is not of a simple order, but appears to be capable of continuous variation.

The conditions for the formation and the character of these urea addition compounds or " adducts " have been studied in detail by W. Schlenk jr. (*Ann. Chem.*, 1949, **565,** 204), who has succeeded in obtaining products of this type with alcohols, ethers, aldehydes, ketones, mono- and di-carboxylic acids, esters, unsaturated hydrocarbons, alkyl halides, amines, nitriles, thioalcohols and thioethers, as well as with paraffins.

The adducts are generally more simply prepared than are the clathrate compounds. It is often sufficient to add the chain compound to a concentrated solution of urea ; for instance, if a saturated solution of urea in methyl alcohol is treated with hexadecane the crystalline adduct separates at once. In other cases, *e.g.* with *n*-valerianic acid, it is better to dissolve the urea in the heated chain compound, when the adduct crystallises out on cooling. It is not always necessary for the urea to be dissolved completely before addition of the second component, adduct formation occurring when finely powdered urea is simply stirred with liquid paraffin hydrocarbons or their solutions in benzene or ethylene dichloride, although in many cases it is advantageous to add a small amount of urea

solvent (water or methyl alcohol) to facilitate the process. Finally, some compounds are even absorbed from the gaseous phase by urea to give these products.

All the urea addition compounds of this new type crystallise in well-formed long hexagonal prisms or hexagonal plates, which grow rapidly to a length of several millimetres or even centimetres. They are therefore readily distinguishable from the tetragonal prisms of urea. In general the adducts have no definite melting-points as they dissociate into their constituents before the melting-point of the crystals is reached.

Unlike either the clathrate compounds of quinol or the addition compounds of the choleic acids, these adducts of urea do not approach any simple molecular composition. In each homologous series of adducts the molecular ratio urea : chain compounds increases linearly with the actual length of the molecular chain. Only slight differences in this respect can be traced on passing from one class of chain molecule to another, and these occur only with the shorter molecules. In this connection two general classes of adducts are distinguishable, paraffins, ketones, and carboxylic esters binding slightly less urea per unit chain length than do carboxylic acids, primary alochols, and primary alkyl halides, an effect which is apparently to be associated with the presence of an active group at the end of the carbon chain in the latter series of compounds.

It is particularly noteworthy that urea most easily adds on straight chain compounds, whilst the addition of branched isomers is more difficult, and in many cases is quite impossible. For instance n-octane gives an adduct easily by adding the hydrocarbon to a saturated solution of urea in methyl alcohol, but 3-methylpentane does not. On the other hand, in the presence of a straight chain paraffin such as n-heptane or n-decane the 3-methylpentane will also enter the adduct. When the chain is more branched still, as with isooctane (2:2:4-trimethylpentane), adducts have not been formed under any conditions. A definite minimum chain length is also necessary before the addition products can be obtained. The actual length depends upon the chemical nature of the chain compound, carboxylic acid and alcohol adducts beginning with n-butyric acid and n-hexyl alcohol, respectively, whilst in the case of ketones even acetone forms an adduct.

The obvious conclusion to be drawn from these observations is that spatial factors must play the decisive role in the formation of the crystals of adduct, but that the factors operating in this case must be very different from those which determine the formation of clathrate compounds. The fact that the compositions of the adducts

are to such a large extent independent of the chemical nature of the chain molecule suggests that the same structural principles must apply to them all.

Examination by X-ray crystallographic methods has shown that a large group of the urea adducts have a similar crystal lattice, typified by that of the cetane–urea compound. The powder diagrams of this group all show the same rings, and hence the chain molecules make no contribution to the interference patterns. This suggests that these molecules have no definite and periodically recurring arrangement in the adduct crystal. The patterns can be explained on the basis of a hexagonal arrangement of the urea molecules, forming a lattice which is less close-packed than that of ordinary urea crystals, but with prismatic holes into which the carbon chains can enter down the centres of the hexagons. The actual cross-section of these prismatic holes, as indicated by the inter-atomic spacings shown by the X-ray diagrams and the known atomic radii, is such that a n-octane molecule, for instance, will fit easily into the hole, and even 3-methylheptane can do so, but the cross-sectional area of the 2:2:4-trimethylpentane molecule is too great to permit its entry. Theoretically a benzene ring would fit very closely into the hole ; actually benzene and its lower homologues do not give adducts, but when a long straight side-chain is introduced, as in octadecylbenzene, a urea adduct of the cetane type is formed. In line with this observation it has also been found that 3-methyleicosane, with its long straight chain and a short branch only near one end, forms the adduct without the presence of another hydrocarbon such as is necessary for 3-methylheptane.

The X-ray studies also show that the elementary cell containing six urea molecules has a length of 11·1 A., so that each urea molecule corresponds to a length of 1·85 A. From the relative proportions of urea and chain molecules in the adducts the average length of hole occupied by each chain molecule can be derived and compared with the length of the molecular chains when stretched to their fullest extent. With n-nonane and n-tetraeicosane it was found that one molecule of hydrocarbon was bound by 7·6 and 17·8 molecules of urea, respectively. These correspond with hole lengths of 14·1 and 33 A., respectively, per hydrocarbon molecule. In the ideal fully extended state these molecules would be 11·7 and 30·6 A. long, respectively, indicating that in each case 2·4 A. is left empty for each molecule included, or else that this is the mean distance between the ends of successive molecular chains. Similar distances are observed also with other types of included molecules. These conclusions are confirmed by the densities of the adducts, which

are in close accord with the values calculated from the crystallographic data and the compositions of the crystals.

The formation of the adducts is exothermic to the extent of 800 to 1350 calories per gram-molecule of urea ; these values are of the order of magnitude usually attributed to van der Waals' forces. Comparison of the values for various series of compounds led Schlenk to the conclusion that about 2800 calories per mole are evolved as a result of the combination of each CH_2-group, whilst the lattice energy of the urea is increased by about 900 calories per mole. The total thermal change comprises these factors together with the energy of separation of the chain molecules from one another and the particular energies associated with the introduction of active groups into the adduct. To these latter factors is attributed the circumstance that in each series there is a minimum chain length below which the adducts are not formed or dissociate very readily in contact with a solvent. The heat evolved in the formation of the adduct decreases with decreasing chain length, and, beyond a certain member, passage into the adduct state becomes thermodynamically impossible. The length of chain at which this state of affairs is attained varies with the groups present in the chain molecule. Some investigations with very long chain compounds indicates that there may also be a maximum length of chain beyond which adducts are not formed. Octaeicosane was found to yield an addition product without difficulty, but the hydrocarbon $C_{55}H_{112}$ did not deposit a urea adduct from benzene solution. Similarly beeswax, which contains myristyl palmitate, gave no adduct. Schlenk suggests that such an upper limit to the chain length suitable for adduct formation is not improbable, owing to the fact that the heats of fusion of these compounds in calories per gram increase rapidly with increasing chain length, so that a limit may be reached beyond which the formation of pure crystals of chain compound may be more favoured energetically than the formation of adduct.

Besides the adducts of the cetane-urea type, a number of urea addition compounds have been obtained which appear to be built up on a different principle, as their diffraction patterns are of a different type. This behaviour is shown by many, but not all, chain molecules which have an active group at each end of the chain, and especially by the $\alpha\omega$-dichloroparaffins. These have not been so fully investigated yet and should prove a very interesting field of study in the future.

As long as the carbon-chain component has a low vapour pressure, as is the case with cetane or stearic acid, the adducts are stable

almost indefinitely in air at ordinary temperature, but the products formed by compounds of higher vapour pressure, such as heptane or dipropyl ketone, undergo more or less rapid decomposition. Unlike the clathrate compounds, however, they have a definite equilibrium vapour pressure and it is a matter of some consequence how this vapour pressure varies as the volatile constituent is progressively removed. If the adducts are to be regarded as arising through adsorption, the vapour pressure should decrease progressively, whereas if they are compounds the vapour pressure would be expected to remain constant. The latter behaviour is observed, and this evidence, together with the constancy of composition of each adduct, leads Schlenk to the opinion that they should be regarded as true compounds just as is $CuSO_4,5H_2O$. The variation of the vapour pressure with temperature leads to values of the heat of dissociation which are in reasonable accord with the observed values.

The adducts all tend to split into their components on stirring with a solvent which dissolves either the urea or the chain compound or both. When only a limited amount of such a solvent is used, however, the dissociation is never complete, but a state of equilibrium between the adduct, chain compound, and urea is attained, with one or both of the latter in solution. The extent of this dissociation tends to increase with rise of temperature. Solvents like water which dissolve the urea very readily lead to a high degree of dissociation even when present in relatively small amounts, but solvents which dissolve the chain compounds cause only a slight dissociation of the adduct. The tendency to dissociate also decreases with increasing chain length of the included molecule, as would be expected from the relative energies of formation of the crystals.

A little evidence that urea and chain molecules of this type associate to some extent even in the liquid phase is provided by the observation that in the presence of urea the solubility in water of n-valerianic acid is greatly increased, whereas the isomeric α-methylbutric acid, which does not form an adduct, is no more soluble than in the absence of urea, showing the effect not to be due merely to salt formation. Also the dissolution of urea in an excess of n-butyric acid and of *iso*butyric acid leads to evolution and absorption of heat, respectively, suggesting a heat of combination in the former case but not in the latter. On the other hand, if such association occurs in the liquid phase it would be expected that compounds like cetane and stearic acid which are insoluble in water would dissolve in urea solutions, but no detectable solubility can be observed in either of these cases.

It is evident that this field is by no means exhausted, and the

discovery of other systems which yield addition products of one of the forms discussed here is to be expected. Structures of this type may well explain other phenomena which have long been rather puzzling, and a reinvestigation of a number of these odd addition products with modern technique and in the light of this present knowledge should form a fruitful field of study.

BIOCHEMISTRY. By C. LONG, M.A., B.Sc., D.Phil., Department of Biological Chemistry, University of Aberdeen.

THE BIOSYNTHESIS OF UREA

ANY review of current work in the field of biochemistry—where advances have been unusually rapid during the last twenty years — must begin at some fairly recent date. The original theory upon which rests the modern conception of the mechanism of urea formation in mammalian liver was first stated in 1932. In that year, Krebs and Henseleit published experiments which represent the first successful attack upon this problem. Their classical observations led them to suggest, in outline, a theory of a closed chain of successive reactions, which they termed the " ornithine cycle." (*See* SCIENCE PROGRESS, 1933, **28**, 294.)

In spite of certain criticisms, later work has amply confirmed the general truth of this theory and has extended it considerably. Many relatively new biochemical techniques have been utilised for this purpose, including, for example, the use of isotopes for tracer work, differential centrifugation of cytoplasmic particles, paper chromatography, the production and study of the metabolism of artificially induced mutants of *Neurospora crassa* and the use of adenosinetriphosphate (ATP) as a primary energy donor in endergonic (*i.e.* energy-requiring) reactions. Perhaps the most notable single achievement in simplifying the study of urea synthesis has been the successful separation of the various enzymatic steps from one another and their subsequent individual study. During the last two or three years, progress has been so rapid that one may now postulate a scheme which explains practically all the known data.

THE WORK OF KREBS AND HENSELEIT

In their first paper (*Klin. Wschr.*, 1932, **11**, 757), these investigators showed that urea was formed when slices of surviving guinea-pig or rat-liver were incubated aerobically in a bicarbonate-saline medium of pH 7·4, containing ammonium chloride and an oxidisable substrate such as sodium lactate ; it was assumed that ammonia

and carbon dioxide were utilised for this purpose. When small amounts of ornithine (I) were also present in the medium, the rate of urea production was markedly increased. The ornithine was found to act catalytically, for its concentration did not fall during the course of the experiment and at low concentration one equivalent of ornithine was able to catalyse the formation of several equivalents of urea. In further work (*Klin. Wschr.*, 1932, **11**, 1137 ; *Z. physiol. Chem.*, 1932, **210**, 33) Krebs and Henseleit demonstrated that liver slices were also capable of forming urea from ammonia and citrulline (II). Since the livers of ureotelic (*i.e.* urea-producing) organisms are well known to be rich in arginase, the enzyme which catalyses the hydrolysis of arginine (III) to ornithine and urea (IV), it became possible to elaborate the theory of the " ornithine cycle." This is shown schematically below, where ornithine is seen to be regenerated at the end of each complete cycle.

$$NH_2(CH_2)_3CH(NH_2)COOH \xrightarrow[- H_2O]{+ CO_2 + NH_3} NH_2CONH(CH_2)_3CH(NH_2)COOH$$
$$(I) \qquad\qquad (II)$$

$$NH_2CONH_2 \qquad +H_2O \qquad\qquad + NH_3 \quad -H_2O$$
$$(IV)$$

$$NH$$
$$\parallel$$
$$NH_2CNH(CH_2)_3CH(NH_2)COOH$$
$$(III)$$
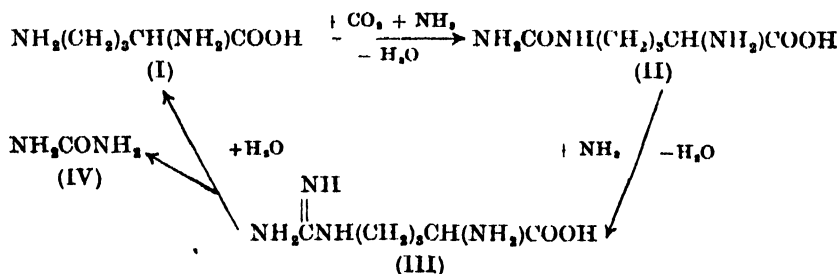
The overall reaction may be represented by the equation :

$$2NH_3 + CO_2 \longrightarrow NH_2CONH_2 + H_2O$$

FURTHER EVIDENCE FOR THE ORNITHINE CYCLE

In recent years many different lines of research have converged to confirm the existence of the Ornithine Cycle. First may be mentioned the work of Gornall and Hunter (*J. biol. Chem.*, 1943, **147**, 593), for although this is a fairly recent investigation, the experiments were carried out with rat-liver slices under conditions very similar to those of Krebs and Henseleit and are complementary to the work already described. Gornall and Hunter showed that citrulline acted catalytically in urea synthesis, using the same criteria as previously stated for ornithine. Earlier, Krebs and Henseleit had been unable to demonstrate this. Next, they determined the relative rates of the three steps of the Ornithine Cycle and found the decomposition of arginine to proceed with the greatest velocity ; the citrulline → arginine step was least rapid and therefore rate-limiting. It followed from this that the addition of ornithine to

respiring liver slices should lead to the accumulation of citrulline, and this was found to be the case. Further, analysis showed that the higher the concentration of ornithine used, the greater the accumulation of citrulline in the medium. This was the first demonstration that citrulline was in fact formed from ornithine by liver tissue and constituted an important piece of evidence in favour of the theory.

Certain *in vivo* experiments using isotopes have also provided support for the Ornithine Cycle. Rittenberg, Schoenheimer and Kcston (*J. biol. Chem.*, 1939, **128,** 603) fed to adult rats a normal diet supplemented with traces of $^{15}NH_4$ citrate ; they detected ^{15}N in the amidino $(NH_2C(=NH)NH-)$ group of the arginine of the tissue proteins and also in the urea excreted in the urine of the rats. Clutton, Schoenheimer and Rittenberg (*J. biol. Chem.*, 1940, **132,** 227) then showed that when ornithine, labelled with deuterium ("heavy hydrogen"), was fed to rats, the arginine present in the tissue proteins also contained deuterium.

In vitro studies by three groups of workers, using isotopic carbon, have demonstrated that the bicarbonate ion may be utilised for urea synthesis. Rittenberg and Waelsch (*J. biol. Chem.*, 1940, **136,** 799) incubated washed rat-liver slices aerobically in a bicarbonate buffer containing $H^{13}CO_3{}'$, together with ammonium chloride, ornithine and glucose ; the urea formed contained ^{13}C. Independently, Evans and Slotin (*J. biol. Chem.*, 1940, **136,** 805) obtained similar results, using bicarbonate labelled with ^{11}C. More detailed information regarding the fixation of CO_2 by ornithine has lately been given by Grisolia and Cohen (*J. biol. Chem.*, 1948, **176,** 929). They showed that when bicarbonate containing $H^{14}CO_3{}'$ was incorporated into citrulline, in presence of an enzyme preparation from rat-liver, the carbonyl-C of the citrulline exhibited the same specific activity as the initial bicarbonate-C. Furthermore, when this labelled citrulline was in turn incubated with another liver enzyme preparation, it formed urea of similar specific activity.

Two other investigations in support of the theory should be mentioned, for they were among the first to shed light on the mechanism of the reactions concerned. The conversion of citrulline to arginine was studied by Borsook and Dubnoff (*J. biol. Chem.*, 1941, **141,** 717) using rat- and guinea-pig-kidney slices. Kidney proved to be very useful for studying this particular reaction, for it has no power to catalyse the conversion of ornithine to citrulline and is also well known to be devoid of arginase. Borsook and Dubnoff found that glutamic and aspartic acids were much better NH_2-donors than was the ammonium ion in this reaction. They suggested a

mechanism for it which they termed " oxidative transimination." This need not be described in detail here, for more recent work has led to a revision of their mechanism and will be referred to later.

An Ornithine Cycle or something very similar has also been found to operate in a group of *arginine-less* mutant strains of the mould *Neurospora crassa*. The wild type of this organism is non-exacting in its aminoacid requirements for growth, for it can synthesise them from the ammonium ion and glucose. By means of X-rays, it has been possible to induce mutations such that the new strains have no power to synthesise arginine, but require either arginine itself or some specific arginine precursor to be added to the growth medium. In all, seven genetically distinct mutant strains were isolated by Srb and Horowitz (*J. biol. Chem.*, 1944, **154**, 129), but four of them could also utilise both citrulline and ornithine, and two others could utilise citrulline but not ornithine. Only one mutant was exclusively dependent on arginine. These data have been taken to indicate that ornithine is the precursor of citrulline, which is in turn the precursor of arginine. Further, the fact that there are two different strains which can utilize citrulline but not ornithine indicates that there must be at least one intermediate step between ornithine and citrulline.

Before passing on to more recent work, brief mention should be made of the fact that the Ornithine Cycle has not been free from criticism and that alternative theories have been suggested. For details, the original papers of Leuthardt (*Z. physiol. Chem.*, 1938, **252**, 238 ; 1940, **265**, 1), Bach (*Biochem. J.*, 1939, **33**, 1833) and Trowell (*J. Physiol.*, 1942, **100**, 432) should be consulted. The objections raised by these workers have generally been attributed to permeability factors and have been adequately answered by Krebs (*Biochem. J.*, 1942, **36**, 758). In any case, the evidence which will be presented in the following sections so overwhelmingly supports the theory that the investigations cited above are now of purely historical interest.

THE ORNITHINE CYCLE AND CELL ORGANISATION

The investigations so far described have all been made under conditions which are often termed physiological ; that is to say, evidence has been obtained both from *in vivo* experiments using compounds containing isotopes and from *in vitro* studies using slices of tissue, material which must be regarded as highly organised. Early attempts to promote urea synthesis in tissue *homogenates* (*i.e.* suspensions of broken cells) or in extracts were without success. The reasons for this are now well understood. The destruction of

cell organisation by grinding in aqueous media is accompanied by dilution of cell contents. Thus, the concentrations of activators such as magnesium ion or adenosinetriphosphate (ATP) are greatly reduced. Furthermore, a hydrolytic enzyme such as adenosinetriphosphatase can now readily come into contact with its substrate ATP and this also causes a loss of activity. However, the enzyme systems in homogenates may frequently be reactivated by adding substrates, activators, etc., to the medium, and when so reconstituted are sometimes more active than the intact cells from which they were derived, for the restrictive influence exerted by cell organisation no longer exists.

The enzymic reactions taking place in urea synthesis have been studied in homogenates, fractionated homogenates and extracts during the last three or four years. By a singular piece of good fortune, it was early discovered that arginase and an enzyme required for the citrulline → arginine step could be extracted from disintegrated cells by means of aqueous media, so that the ornithine → citrulline stage could be studied separately with the insoluble residue. In the rest of this article, the individual steps in the Ornithine Cycle will be discussed in turn in the light of recent research.

THE ORNITHINE → CITRULLINE STEP

Borsook and Dubnoff (*J. biol. Chem.*, 1947, **169**, 461) were the first to demonstrate the conversion of ornithine into citrulline by respiring homogenates of guinea-pig-liver. They found that maximal activity required not only ornithine, ammonium and bicarbonate ions but also a supply of energy, for the overall reaction is well known to be endergonic. Further supplementation of the medium with glutamic acid, oxaloacetic acid and traces of ATP ensured the continual regeneration of energy-rich phosphate bonds. Almost simultaneously, Cohen and Hayano (*J. biol. Chem.*, 1947, **170**, 687) observed the aerobic synthesis of citrulline from ornithine in rat-liver homogenates. In their system, maximal activity was obtained when the respiration medium contained ornithine, bicarbonate, ammonium, potassium and phosphate ions, glutamic acid and ATP. If magnesium ions were also added to the medium, the yield of citrulline was markedly reduced, due to its further conversion, by way of arginine, to urea.

In a later study, Cohen and Hayano (*J. biol. Chem.*, 1948, **172**, 405) showed that the enzyme complex responsible for the ornithine → citrulline reaction was associated with the insoluble particles of a rat-liver homogenate, whereas part of the system catalysing

the citrulline → arginine step was water-soluble. This was a major technical advance, for by centrifuging a homogenate it became possible to study these two phases of the Ornithine Cycle in separate fractions. Using the insoluble liver residue, it was found that in addition to the components mentioned earlier, magnesium ions were also required for full activity in the ornithine → citrulline step. This is in agreement with the general need for magnesium ions in reactions involving phosphorylation.

The main findings of Cohen and Hayano have been confirmed by Leuthardt, Müller and Nielsen (*Helv. Chem. Acta*, 1948, **32**, 744), who have used for their experiments a suspension of washed rat-liver mitochondria. This is a more highly fractionated preparation than the liver residue of Cohen and Hayano, which latter contains nuclei as well as mitochondria. The Swiss workers have also shown that malonate strongly inhibits citrulline formation. This effect is explained by the blocking of the succinate → fumarate stage of the tricarboxylic acid cycle and by the consequent inhibition of the oxidation processes which are coupled with ATP regeneration. As might be expected, fumarate addition was able to cancel the inhibition by malonate. Another observation made repeatedly by these workers was that at high concentration, glutamine could replace glutamic acid plus ammonium ions and, indeed, was two or three times as effective, catalytically. No obvious explanation for this finding has been forthcoming, but it has been mentioned here because it is an effect which, if confirmed, will have to be explained before the complete mechanism of the ornithine → citrulline step can be known. It should also be mentioned, however, that Cohen and Hayano obtained only small and very variable effects with different samples of glutamine when used in a concentration similar to that of Leuthardt *et al.*

The present conception that the synthesis of citrulline involves the transfer of a completely preformed carbamyl group ($-CONH_2$) to ornithine was first suggested by Leuthardt and Glasson (*Helv. Chem. Acta*, 1942, **25**, 630). Leuthardt and Brunner (*Helv. Chem. Acta*, 1947, **30**, 958) maintained that the alternative mechanism, *viz.* the successive addition of CO_2 and ammonia to ornithine, was unlikely, although it had earlier been assumed to be the most probable pathway (Krebs, *Ann. Rev. Biochem.*, 1936, **5**, 262). Cohen and Grisolia (*Federation Proc.*, 1948, **7**, 150) obtained evidence that the primary CO_2-acceptor was glutamic acid rather than ornithine ; this, of course, would account for the importance of glutamic acid in the synthesis of citrulline. Further work by Cohen and Grisolia (*J. biol. Chem.*, 1948, **174**, 389), with a large series of compounds

which might have been expected to behave catalytically in the ornithine → citrulline reaction, showed that only carbamyl-glutamic acid (V) was highly active, a fact later confirmed by Leuthardt *et al.* (1948).

Very recently, Cohen and Grisolia (*J. biol. Chem.*, 1950, **182**, 747) have published details of their studies. They find that if the liver residue is first incubated aerobically with glutamic acid, ATP, ammonium, bicarbonate, magnesium, phosphate and potassium ions, then the addition of ornithine and further incubation under anaerobic conditions leads to citrulline formation. This is consistent with the endergonic synthesis of carbamylglutamic acid in the first stage, followed by transfer of the carbamyl group to ornithine. In a footnote to their paper, Cohen and Grisolia state that they have now succeeded in extracting from rat-liver residue an enzyme, *transcarbamylase*, which catalyses the anaerobic synthesis of citrulline from ornithine and carbamylglutamic acid. All the evidence now points to the following scheme for citrulline synthesis :

$$
\overset{\displaystyle \overset{NH_2}{|}}{HOOCCH_2CH_2CHCOOH} + HCO_3^- + NH_4^+ \longrightarrow
$$
$$
\text{glutamic acid}
$$

$$
\overset{\displaystyle \overset{NHCONH_2}{|}}{HOOCCH_2CH_2CHCOOH} + 2H_2O \qquad . \quad (1)
$$
$$
\underset{(V)}{\text{carbamylglutamic acid}}
$$

$$
\text{carbamylglutamic acid} + \text{ornithine} \longrightarrow \text{glutamic acid} + \text{citrulline} \qquad . \quad (2)
$$
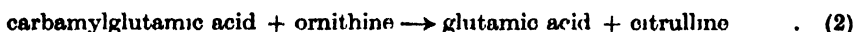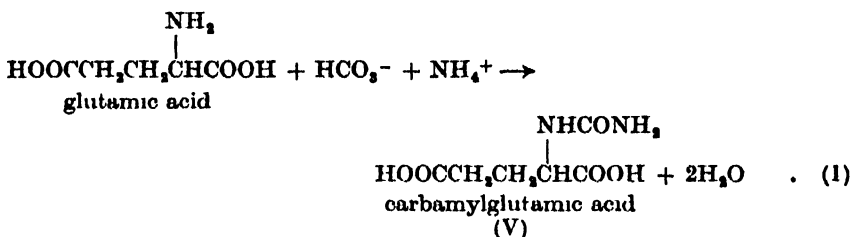
Reaction (1) requires ATP, magnesium ions and aerobic conditions, while reaction (2) needs only the enzyme transcarbamylase. Glutamic acid thus appears as a catalyst, being utilised in reaction (1) and regenerated in reaction (2).

Before leaving the discussion of the ornithine → citrulline phase of urea synthesis, the dependence of this reaction on the nutrition of the animal should be mentioned. MacLeod, Grisolia, Cohen and Lardy (*J. biol. Chem.*, 1949, **180**, 1003) have shown that, when a rat is fed on a biotin-deficient diet, its liver is only about 50 per cent. as active as normal rat-liver in the synthesis of citrulline. The activity can be restored to normal values, however, by addition of a boiled extract of normal liver (in which the enzymes have been inactivated) but not by biotin itself. These results are in accord with the reduced rate of other types of CO_2-fixation observed in biotin-deficient organisms and strongly suggest that biotin is part of a coenzyme required for CO_2-uptake.

THE CITRULLINE → ARGININE STEP

Reference has already been made to the work of Borsook and Dubnoff (1941), who studied the synthesis of arginine from citrulline by kidney slices and found glutamic acid to be an obligatory metabolite in this system ; they suggested that the reaction involved an " oxidative transimination," the overall result of which was represented by :

glutamic acid + citrulline + $\frac{1}{2}O_2 \rightarrow$ α-ketoglutaric acid + arginine + H_2O
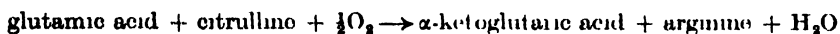
The citrulline → arginine phase of urea synthesis was later studied by Cohen and Hayano (*J. biol. Chem.*, 1946, **166**, 239 ; 251) who found a rat-liver homogenate to be the most active tissue preparation investigated. Maximal activity was obtained when the homogenate plus citrulline was supplemented with ATP, glutamic acid and magnesium ions under aerobic conditions ; no synthesis of arginine was detected anaerobically. It will be noted that these requirements are rather similar to those needed for the ornithine → citrulline phase. This is partly due to the fact that both steps are endergonic. In later work, Cohen and Hayano (*J. biol. Chem.*, 1948, **172**, 405), as previously stated, showed that while the ornithine → citrulline step was catalysed by enzymes present only in the insoluble residue of rat-liver, the citrulline → arginine step needed both the insoluble residue and the supernatant. However, in this latter step, the rat-liver residue could be replaced by particulate material from other tissues such as heart or muscle, though homogenates of these latter tissues were by themselves quite incapable of promoting arginine synthesis from citrulline. It was concluded that the insoluble matter was simply providing the enzymes of the tricarboxylic acid cycle, which catalyse the oxidative processes needed for regeneration of ATP. The supernatant was presumed to contain a soluble enzyme capable of catalysing the transfer reaction.

The mechanism of the enzymic reactions catalysed by this supernatant from rat-liver homogenate has been clarified by the recent work of Ratner (*Federation Proc.*, 1949, **8**, 603). Ratner and Pappas (*J. biol. Chem.*, 1949, **179**, 1183 ; 1199) used only the supernatant fraction from rat-liver homogenates. The ATP-generating system was supplied by the well-known transphosphorylation reaction of glycolysis (SCIENCE PROGRESS, 1949, **37**, 283).

2-phosphopyruvate + ADP ⇌ pyruvate + ATP.

In consequence, the complete system was independent of oxidative processes and could take place under anaerobic conditions. In this way it was found that the amino-group for arginine synthesis was

derived from aspartic acid rather than glutamic acid. Indeed, glutamic acid was quite inactive, except in the presence of oxalo-acetic acid, when the formation of aspartic acid by transamination was presumed to take place. Furthermore, in contrast with earlier work, no changes in the state of oxidation of the metabolites accompanied the transfer, for one equivalent of l-malic acid was formed for each equivalent of citrulline utilised, the overall equation being written :

$$\text{aspartic acid + citrulline} \longrightarrow l\text{-malic acid + arginine.}$$
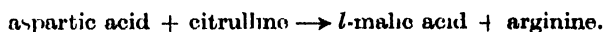
Nevertheless, the reaction was believed to take place in two stages, represented as follows :

$$
\begin{array}{c}
\text{NH} \\
\parallel \\
\text{RNH—C—OH} + \text{H}_2\text{N - CH.COOH} + \text{ATP} \longrightarrow \\
\mid \\
\text{CH}_2\text{COOH}
\end{array}
$$

<div style="text-align:center">

citrulline   aspartic
(enolic form)   acid

</div>

$$
\begin{array}{c}
\text{NH} \\
\parallel \\
\text{RNH—C—NH—CH.COOH} + \text{ADP} + \text{H}_3\text{PO}_4 \quad . \quad (3) \\
\mid \\
\text{CH}_2\text{COOH}
\end{array}
$$

<div style="text-align:center">intermediate</div>

$$
\begin{array}{c}
\text{NH} \\
\parallel \\
\text{RNH—C—NH—CH.COOH} + \text{H}_2\text{O} \longrightarrow \\
\mid \\
\text{CH}_2\text{COOH}
\end{array}
$$

<div style="text-align:center">intermediate</div>

$$
\begin{array}{c}
\text{NH} \\
\parallel \\
\text{RNH—C—NH}_2 + \text{HO--CH.COOH} \quad . \quad . \quad (4) \\
\mid \\
\text{CH}_2\text{COOH}
\end{array}
$$

<div style="text-align:center">arginine l-malic acid</div>
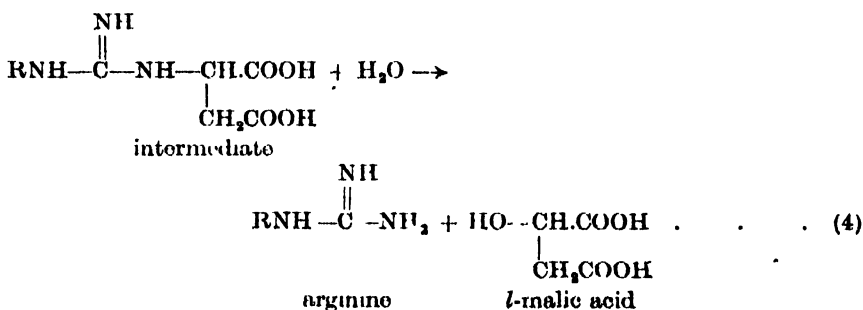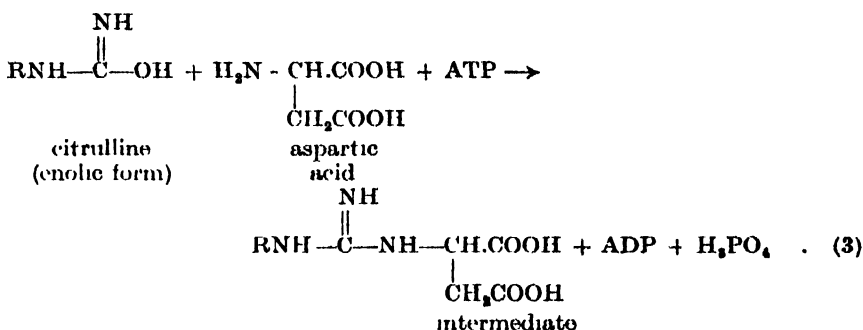
The evidence supporting this two-stage reaction in the conversion of citrulline to arginine was provided by the successful separation of two distinct enzymes from the supernatant. Enzyme A catalysed the condensation reaction (3), while another enzyme B was needed for the succeeding hydrolytic stage (4). By first mixing the reactants in the presence of enzyme A, citrulline disappeared and an equivalent of inorganic phosphate was liberated ; addition of enzyme B was required for the formation of equivalent amounts of arginine and l-malic acid.

The earlier observations of Cohen and Hayano, with whole homogenates and glutamic acid, are explained by the fact that this substance is readily deaminated to α-ketoglutaric acid which is an intermediate in the tricarboxylic acid cycle. Thus oxaloacetic acid is formed which is converted into aspartic acid by transamination with unchanged glutamic acid. In addition, the tricarboxylic acid cycle provides the necessary energy for continued resynthesis of ATP. Müller and Leuthardt (*Helv. Chem. Acta*, 1950, **33**, 268) have confirmed this role for glutamic acid ; by means of paper chromatography (SCIENCE PROGRESS, 1947, **35**, 299) they have demonstrated the formation of aspartic acid when glutamic acid is added to rat-liver homogenates, under the conditions used by Cohen and Hayano.

THE ARGININE → ORNITHINE + UREA STEP

This phase has never provided any obstacle to the acceptance of the Ornithine Cycle ; indeed, it has always been the least controversial. Although the enzyme arginase, which catalyses the reaction, is not widely distributed in animal tissues, it is abundantly present in the liver, so that arginine does not accumulate ; the arginine → ornithine step is never rate-limiting. The purified enzyme has been studied by several workers ; it is soluble in water, has a high *p*H optimum and its only requirement for activity appears to be manganous ion.

GEOLOGY. By G. W. TYRRELL, A.R.C.Sc., D.Sc., F.R.S.E., The University, Glasgow.

GRANITISATION, METASOMATISM, METAMORPHISM AND TECTONICS

THE great granitisation controversy still goes on merrily and the big guns, not to say the atom bombers, on both sides have come into action. Two symposia have been held, which have done much to clarify the issues. The first is reported in *Memoir 28* of the Geological Society of America (1948) ; the second in the *Report of the International Geological Congress*, 18th Session (Great Britain, 1948), Pt. III, 1950. Opinion seems to be rapidly crystallising to H. H. Read's common-sense conclusion that there are " Granites and Granites " (*Geol. Soc. Amer. Mem. 28*, 1948, 1–19). There is, he suggests, no unique solution of the problem, and " no need for an *either-or* attitude." The problem is essentially one of the interpretation of the facts of the field. To Read, the making of granite, migmatisation and regional metamorphism are all parts of the one process which, following Lyell, he has styled *plutonism*. Volcanism is essentially different and separate from plutonism in its nature

and geological setting. Read gives a masterly summary and criticism of the magmatic theory of the origin of granite, and discusses such topics as the room problem, the granitisation process, the occurrence of feldspars in the adjacent country rocks identical with those of the granite, diffusion in the solid (on which he suspends judgment), the plutonic rocks, and "mobilisation." The conclusion is : " Whether as migma or, if the process goes far enough, as magma, granitic material may move into higher levels of the crust and produce there the discordant granite bodies with aureoles of thermal metamorphism." There might thus arise a *granitic series* depending on the mobility of the material. Termier's opinion that granites with a narrow aureole of thermal metamorphism are magmatic, while those surrounded by vast masses of regionally metamorphosed rocks have been made by processes of granitisation, seems to be eminently reasonable. This view is reinforced by Raguin's classification, *granites d'anatexie* and *granites en massifs circonscrits.* In other words there are granites—and granites !

Professor Read further clarifies his position in his second Presidential Address to the Geological Society of London on " A Contemplation of Time in Plutonism " (*Quart. Journ. Geol. Soc.*, CV, 1949, 101–56). " As the whole operation of plutonism," he says, " depends upon the activity of migma-magma, it is necessary to deal with the time relations of crystallisation, deformation, granitisation, migmatisation, metamorphism, intrusion and orogeny." The concept of the Granite Series " attempts to relate the plutonic phenomena at the various levels of exposure, and to give a unity to the processes of granitisation, migmatisation and metamorphism at depth, and at successively higher positions and later times.

" The series begins with the autochthonous granites associated with migmatites and metamorphites produced *in situ* in the depths. The movement of the granitised material provides the successive terms of the series. The parting of envelope and core, the structural control of movement, straining off, selective mobilisation, overtaking, and chemical variation in the series, are discussed. The Granite Series ends with the late high-level plutons emplaced as viscous masses." The Granite Series is thus viewed as " linking granites in time, place and character. Place may vary vertically or horizontally, time differences may be small or immense, characters may be seemingly, inconstant." But, " although there may be granites and granites, most of them are of one kind, and all of them may likely be of one connected origin." The two Presidential Addresses of Professor Read are likely to become classics of this fundamental study.

G. E. Goodspeed is one of the few American geologists who incline decidedly to the metamorphic and metasomatic theories of the " Origin of Granites " (*Geol. Soc. Amer. Mem. 28*, 1948, 55-78). He concentrates especially on field evidence and textural criteria, and describes transitional facies (replacement dikes, replacement breccias and metamorphic migmatites). Goodspeed does not pronounce on the relative efficiency of the " wet " and " dry " methods of diffusion, but appears to admit the possibility of both processes. He seems to stand with the exponents of the middle position that there are granites—and granites.

In three long papers P. Misch, " Metasomatic Granitisation of Batholithic Dimensions ": Part I. " Synkinematic Granitisation in Nanga Parbat Area, NW. Himalayas " (*Amer. Journ. Sci.*, **247**, 1949, 209-45) ; Part II. " Static Granitisation in Shoku Area, NW. Yunnan (China) " (*ibid.*, 372-406) ; Part III. " Relationships of Synkinematic and Static Granitisation " (*ibid.*, 673-705), makes a very remarkable contribution to the granitisation controversy. In the first paper Misch takes up much the same position as Read's (although Read's name does not figure in his Bibliography) when he writes : " I wish to emphasise the general validity of the statement that high-grade regional metamorphism and synorogenic granitisation are invariably and necessarily linked." In the Himalayan region which he describes, a thick series of ancient argillites with thin calcareous bands has been subjected to regional metamorphism during Early Tertiary orogeny. " Synkinematic metamorphism of the argillites progresses from slates and phyllites through mica-schists and paragneisses to sillimanite-paragneisses." Granitisation of the potash-predominant variety begins in the kyanite zone with porphyroblasts of microperthite, passing to potash-rich augen-gneisses of granitic aspect containing relict kyanite. *Lit-par-lit* replacement along active foliation planes produces banded gneisses. In the interior of the Nanga Parbat massif the process ends with a massive, coarse-grained granitic gneiss. The calcareous layers are not granitised but are preserved as conformable intercalations in the gneissose granite. There is complete structural continuity from the weakly metamorphosed area to the intensely granitised region. This is clearly one of the most complete examples of progressive granitisation yet described. The transformations have been effected by " granitising solutions." Most emphatically Misch is not a " dry " !

The second paper on static granitisation deals with granodiorite-porphyries which are believed to have been formed by the metasomatic replacement of Mesozoic " red beds " in Yunnan. Stratifica-

tion and the clastic textures of the sediments are largely preserved in the ensuing granodiorite-porphyries. The phenocrystic oligoclase, microperthite and quartz of the porphyries are porphyroblasts showing replacement features. Metasomatism took place at shallow depths and at a moderate temperature by rising solutions containing alkalis, especially soda.

The third paper is of a general character and draws together the facts and conclusions from the study of the Nanga Parbat and Yunnan areas. We quote from the excellent summary to this paper : " Genetically, synkinematic granitisation is presented as a fundamental process in geosynclinal orogeny, and static granitisation as its continuation after the end of orogeny. Post-orogenic conditions favour a carrying of the process into higher levels of the crust. Where only static granitisation is visible, the products of previous synkinematic granitisation may be concealed at depth. Granitic batholiths are considered as predominantly metasomatic, and the rise of magma in broad fronts to shallow levels without breaking through as unlikely. Mobilisation of metasomatised rock masses may more locally occur as a still more advanced stage of granitisation. To sum up, genetic unity of synkinematic and static granitisation in geosynclinal belts is emphasised." We regard this series of papers as one of the best statements of the moderate granitisation position.

Most magmatists would admit that it would be very easy for arkoses to be transformed into granite, and for basalts and dolerites to be turned into gabbros, by simple metasomatic processes. An excellent instance of the transformation of arkose is reported by H. A. Coombs in his paper on " Granitisation in the Swauk Arkose near Wenatchee, Washington " (*Amer. Journ. Sci.*, **248**, 1950, 369–77). Along the axis of an anticline the arkoses have been locally transformed into a rock having the composition and texture of granodiorite. " The various steps in the granitisation process can be traced from the initial stages wherein the quartz is enlarged by secondary growths, and the plagioclase is rimmed with clear albite, to the final stage resulting in a coarse-grained rock of interlocking crystals devoid of interstitial matter." The process seems to have taken place at comparatively low temperature, and only an extremely small amount of solutions may have been needed for the transformation.

Dr. Doris L. Reynolds's paper " Observations concerning Granite " (*Geol. en Mijnb.*, **11**, No. 8, 1949, 241–53) presents as thorough a discussion and review of literature as Read's, combined with her own extensive observations on the subject, but from the more

extreme Transformist standpoint. She discusses critically the original observations of Hutton on granite veins, and concludes that, while they are undoubtedly statements of fact, they do not bear the conclusion that Hutton drew from them, namely, that the granite was injected in the magmatic state. Great play is made with the now common observation that pods of granitic material are found completely isolated within the adjacent schists, etc., and MacCulloch's neglected observations of 1816 on this phenomenon at Hutton's classic locality of Glen Tilt are brought into service. (The writer would like to be assured of the correctness of Mac-Culloch's petrographical identifications on which much of the argument hangs.) Dr. Reynolds claims that "the Transformist interpretation of granite . . . satisfies the structural requirements, solves the space problem or at the worst reduces it to negligible proportions, and provides an explanation of the association with granite of basic roof-rocks and inclusions, and of aureoles of Fe-Mg enrichment."

In his paper "Some Observations on Homogenization and on Geochemical Discontinuities in Granitic Areas," H. G. Backlund (*Inter. Geol. Congr., 18th Session, Great Britain 1948, Report Part III*, 1950, 31–44) endeavours to establish the proposition that the structural and textural peculiarities of megaporphyritic granites, and even-grained granites, can be correlated with the respective tectonic styles of the sedimentary formations within which they are emplaced. The former are developed by the transformation of sediments of fairly equal competence with harmonious isoclinal folding. The even-grained granites, on the other hand, are developed within sediments of varying competence that show crumpling and disorderly folding. The highly involved reasoning and the geochemical considerations on which these generalisations are based are difficult to understand ; but that may be the writer's fault. Professor Backlund's mental eyes have the same faculty of piercing solid granite as Sam Weller's imaginary eyes had of penetrating a brick wall. Backlund points out that geochemical discontinuities in the ores associated with granitic masses militate against the theory of their magmatic origin but, on the other hand, harmonise with geochemical discontinuities within the sedimentary rocks from which granites have been developed according to the Transformist theory. On the other hand, Backlund believes in the gradual "homogenisation" of granites through the continued operation of the transforming agencies—a process which might be thought to have "ironed out" the geochemical discontinuities also.

The following is a summary translation of the Abstract of C. E. Wegmann's paper, " Transformations métasomatiques et Analyse tectonique " (*Inter. Geol. Congr.*, *18th Session*, *Great Britain 1948*, *Report Part III*, 1950, 45–52) : " The idea of the transformation of sediments has its roots in stratigraphical and tectonic studies, for both Pre-Cambrian and Post-Cambrian terrains. Sederholm found that he could only succeed with the aid of the metamorphic principles developed by the early French school. These origins are important for the logical structure and evolution of Transformism. The development of physical chemistry and the application of its rules to petrological problems has limited the field of view of many researchers to physico-chemical interpretations. These schools are inspired, each in its own way, by laboratory data, ending with the aid of extended extrapolations in very different results ; but the framework of stratigraphical, tectonic and kinematic facts must delimit the field of extrapolation. The progress of tectonic analysis permits the construction of a framework exhibiting the phenomena from the angle of geochemical tectonics. Wegmann, as shown by previous work also, is of the school of Backlund and Reynolds, with a tendency to stress the tectonic aspect of Transformism. "

Granitisation of geosynclinal sediments in an orogenic setting is now a widely accepted theory, but the purpose of D. L. Reynolds's paper " The Transformation of Caledonian Granodiorite to Tertiary Granophyre on Slieve Gullion, Co. Armagh, Northern Ireland " (*Inter. Geol. Congr.*, *18th Session*, *Great Britain 1948*, *Report Part III*, 1950, 20–30) is to describe an occurrence of granitisation within a kratogenic setting. In this paper she describes a spectacular series of changes whereby the Caledonian granodiorite of Newry has been transformed into typical Tertiary granophyre. The initial stages of transformation appear within the solid granodiorite as it approaches the down-faulted Tertiary volcanic pile of Slieve Gullion. More advanced changes are found within definite horizons of explosion breccias. The transition is illustrated by nine chemical analyses which, when plotted, give a regular variation-diagram.

Dr. Reynolds, in collaboration with A. Holmes, has also published a paper on " A Front of Metasomatic Metamorphism in the Dalradian of Co. Donegal " (*C.R. Soc. Géol. Finlande*, No. 20, 1947), which the writer unfortunately has not yet seen, but it doubtless represents a further illustration of the doctrine of " fronts " which is associated with these authors.

In a memoir on " The Geology of the Osi Area, Ilorin Province," B. C. King and A. M. J. de Swardt (*Geol. Surv. Nigeria, Bull. No. 20*, 1949, 92 pp.) describe and discuss a complicated succession in

the Pre-Cambrian Complex of Nigeria. Within an Older Gneiss Complex at least one of possibly several granite cycles has been recognised. These gneisses were later invaded by sheets of basic rocks (metagabbro). The whole complex was then penetrated by a large mass of coarse porphyritic granite. The authors discuss the study of textures in petrogenetic interpretations, the significance of " fronts " in granitisation in relation to ionic mobility, and the relations between granite emplacement and structures. Further, they adopt the conclusions of Lapadu-Hargues concerning the order of mobility of common elements in transformation processes, *i.e.* K (least), Ca, Na, Mg, Fe (greatest). Yet, as Bowen says, the large K atom, " must be assumed to be among the most susceptible to solid diffusion if granites are to be formed by that process. Moreover Mg . . . is both lighter and smaller than K. Why does Mg lag behind in this process of granitisation by solid diffusion ? " The authors favour, on the whole, the " dry " granitisation processes. This memoir is outstanding for its clarity and excellent mode of presentation. The Geological Survey of Nigeria is to be congratulated on publishing a purely theoretical and scientific memoir notwithstanding its dominant economic preoccupations.

With R. Perrin and M. Roubault (" On the Granite Problem," *Journ. Geol.*, **57**, 1949, 357-79, and earlier papers) we reach the " dry diffusion " extremists. After some criticism of the magmatic theory the authors present evidence that " granite originated by diffusion and reaction in the solid state." This evidence is practically the same as that which is used by the " wet " transformists to support their position, and by magmatists to explain pegmatites, etc. Perrin and Roubault impartially attack both ; both are accused of giving way to " anthropomorphic or subjective impressions " (whatever they are). But we think the present authors are by no means free from these intellectual vices. The whole paper is highly controversial in tone. The theory of dry diffusion as the main agent in granitisation is referred to later when dealing with the contributions of Bowen and Jagitsch to the problem.

The same authors have re-asserted their position on " Metamorphism of the Trias in the Alps " (*Geol. Mag.*, LXXXVII, 1950, 89–101) which was so devastatingly criticised by M. Lugeon and later by O. T. Jones (*see* SCIENCE PROGRESS, July 1949, p. 520). To quote from the latter reference : " The basal Trias rests with great unconformity on ancient schists, gneisses and granites. . . . A reddening effect is seen in the rocks underlying this and similar unconformities, whether metamorphic or not, and is attributable to contemporaneous weathering. In the Scheidnössli section the

unconformity is marked by a peculiar arkose about 12 ft. thick, which grades downwards into a gneiss, but is sharply truncated above by the base of the Trias. This in interpreted as due to ' disintegration *in situ.*' But Perrin and Roubault claim this arkose as a product of post-Trias metamorphism which, with the subjacent gneiss, is regarded as due to granitisation working up from below, the [transforming agents] being blanketed off by the Trias which is assumed to have acted as a barrier to the transforming processes." In the present paper Perrin and Roubault have brought forward new evidence and further arguments in support of their views, but we think that the great majority of geologists will remain unconvinced. They seem to take up the position that the whole geological army is all out of step except them.

In P. Eskola, " The Nature of Metasomatism in the Processes of Granitisation " (*Inter. Geol. Congr. 18th Session, Great Britain 1948, Report Part III*, 1950, 5–13) we have the exponent of " wet " diffusion involving original granitic magma within the foundations of the great gneiss-granite massifs. He shows that in the various types of sedimentary and metamorphic rocks which are subject to granitisation, the chemical change into " granite " is best explained by the " mass action of granitic magma which soaked into the rock," with fixation of the substances needed by the invaded rock, and expulsion of those not needed to turn them into granites. Thus, the granitisation of quartzite would mean the addition of all oxides in varying amounts except silica, and a large amount of silica would be expelled.

Characteristic of this kind of metasomatic granitisation is the constant occurrence of intermediate stages and of relict structures, such features being " lacking in those granites that otherwise prove to have crystallised from liquid magmas such as the Rapakiwi, the synkinematic differentiated intrusives (the ' urgranite ' of Sweden), or the graphophyric granites differentiated from dolerite." The bulk composition of these granites, " whose magmatic origin is beyond any doubt," may be identical with that of granites derived from sediments, which is regarded as strong evidence that liquid magma has been the ultimate source of material in all cases.

Eskola shows that the metasomatic changes have not occurred at constant volume ; hence the swelling into domes and upward intrusion, which are invariable features of granitisation.

N. H. Magnusson, in his paper on " The Origin of the Sörmland Gneisses " (*Inter. Geol. Congr., 18th Session, Great Britain 1948, Report Part III*, 1950, 14–19) shows that these veined gneisses are

more or less strongly altered leptites, slates and granites, with a long and complicated history. This alteration was caused by granitic emanations and solutions coming from deeper zones of the earth's crust where palingenetic processes were in operation. The original rocks have been altered in such a way that enrichment in the most stable constituents, and impoverishment of the more soluble constituents, have taken place, resulting in a decrease in silica, alkalis and calcium, and an increase in Al, Fe and Mg. Magnusson finds it necessary to assume that the emanations and solutions from the depths soaked their way through the strongly schistose complex with its iron ores and limestones. In the roof of the veined gneisses the solutions have given rise to cross-cutting pegmatites, granites and mica-schists of metamorphic derivation. His point of view therefore approximates to that of Eskola.

In his study, " Ueber Verschiedenheiten im Verlaufe magmatischer und metamorpher Prozesse, erläutert an Beispielen aus dem Aarmassiv," H. F. Huttenlocher (*Mitt. Naturf. Ges. Bern*, (NF), 4, 1947, 85–116) considers granite intrusions and granitisations which, in the Aar Massif, are differently developed according to their geotectonic arrangement and structural level. In some districts true juvenile magmatic melts occur on high structural levels where they cooled quickly, and show few or no " adjustment processes " with the adjacent rocks. On the other hand, in other regions where " granite " is exposed at deep structural levels, reactions between the melts and the adjacent rocks lead to the " hybridisation of the whole granite mass." The intimate " acid " penetration of rocks immediately adjacent to the Aar Massif has not been caused by these melts, but by anatectic material mobilised by orogenic movements at geosynclinal depths. In the Erstfelder Gneiss and other masses anatectic granitisation has reached a very advanced stage. Here again, Huttenlocher's standpoint is that of Eskola's.

In a paper on " Tectonics of the Mt. Aigoual Pluton in the Southeastern Cevennes, France, I and II " D. de Waard (*Proc. Kon. Nederl. Akad. Wetensch.*, LII, 1949, No. 4, 389–402 ; No. 5, 539–50) shows that in this granite pluton the mechanism of intrusion has been doming of the roof and not stoping. Domes of flow structures, slates dragged upwards near the contacts, drag-faults indicating raised blocks near the pluton, and long-distance faults showing arching of the roof, provide evidence of a magma forced upwards, and enlargement of the magma chamber by doming of the roof.

Thus the structures of the Mt. Aigoual pluton (and of all the granite massifs of the Cevennes so far as observed), and the narrow

zones of contact metamorphism, prove the existence of " magma or mush," and magmatic flow. " The granite has been a mobile substance during its *mise en place*, and there are no indications [of] metamorphic diffusion in the present magmatic deposit. No evidence has been found bearing on the origin of the mobile granite mass in depth before its intrusion."

R. C. Heim describes the petrology of the above granite (*ibid.*, No. 6, 676–84). His most noteworthy observation is that textural and structural features indicate that a long process of crystallisation and re-crystallisation had been going on prior to, and during the, emplacement of the pluton.

In two recent papers, " Magmas " (*Bull. Geol. Soc. Amer.*, **58**, 1947, 263–79) and " The Granite Problem and the Method of Multiple Prejudices " (*Geol. Soc. Amer. Mem. 28*, 1948, 79–90), N. L. Bowen makes powerful and penetrating criticisms of the granitisation theories from the Magmatist viewpoint. He says, however : " There is probably no magmatist who does not believe that igneous and especially granitic material has occasionally been introduced into and replaced other rocks to such an extent that they acquire the composition of granite. He does reject the contention that most granitic rock has been formed by this process of granitisation. Similarly there is probably no upholder of the metamorphic view who does not accept the possibility of a little granitic magma on occasion. . . . The real question is, then : How much granite is magmatic and how much metamorphic ? " Thus, again, we have the view that there are granites—and granites.

Bowen is especially critical of the views of the " dry " granitisers on physico-chemical grounds. His conclusion is that solid diffusion may explain some synantectic phenomena (coronas, reaction-rims, etc.), but it is highly improbable as a major factor in geological processes such as granitisation. His main objection to large-scale " wet " granitisation is based on the huge supply of energy it requires for which no source is in sight. Furthermore, the space-problem is just as difficult and insistent for Transformists as for Magmatists.

Bowen's criticism of " dry " diffusion as the main agent of granitisation is powerfully reinforced by the results of R. Jagitsch in a note on " Geological Diffusions in Solid Phases " (*Nature*, **164**, Sept. 17, 1949, 497–8). He shows that, in a most favourable case of diffusion of Na_2O in AlSi compounds at temperatures close to the melting-point, the velocity of diffusion is so small that in 10^8 years the reaction layer could attain a thickness of only a few dozen feet. He thus comes to the conclusion that diffusion in solid

phases cannot play any important part in the transport of matter over long distances.

In a paper on " Granite and Metasomatism " the veteran and versatile geologist and petrologist R. A. Daly (*Amer. Journ. Sci.*, **247**, 1949, 753–78) enters the granitisation controversy decidedly on the Magmatist side. The paper " is intended to show that the [Transformists] have not thought to scale, have neglected many vital facts bearing on the problem, and have in no wise weakened the arguments of the Magmatists which have led towards what appears to be a sound theory of the evolution of the earth's crust." He takes the same view of the energy problem, of " dry " diffusion and of " homogenisation " as Bowen does. Daly, true to his life-long preoccupation with petrological tectonics and the earth-shells, claims that Transformists have not sufficiently considered the relations of metasomatism of the granitisation type to the Archæan basements which represent the nearest accessible approach to the Sial layer. Why, too, he asks, is the Sial shell largely confined to one hemisphere, and why has the basaltic substratum of the Pacific hemisphere escaped granitisation ? He lists twelve kinds of " argumentative trouble " for Transformists, and thinks that Magmatists have provided better answers for at least some of the questions he formulates.

PEDOLOGY. By G. V. JACKS, M.A., Commonwealth Bureau of Soil Science, Rothamsted Experimental Station, Harpenden.

THE ROLE OF THE SOIL FAUNA IN SOIL FORMATION.—A feature of recent pedological research has been the increasing recognition that soil formation is essentially a biological phenomenon. In Russia, indeed, it is very rare for a pedological paper to be published without the author going out of his way to show that he is approaching his subject strictly from the biological angle. Elsewhere, also, increasing attention is being paid to the role of living organisms in transforming a geological rock or deposit into soil. Formerly, the main interest was directed to the role of micro-organisms, but latterly the emphasis has switched to the smaller macro-organisms—insects, arthropods, earthworms, etc.—which, taken together, are believed by many biologists to be more important soil-forming agents than micro-organisms.

The early work of Charles Darwin (*The Formation of Vegetable Mould through the Action of Earthworms*, 1881), who showed that worms move 7–14 tons of subsoil to the surface annually, and that they ingest large quantities of plant residues and excrete them in

a humified form and intimately mixed with mineral particles, has been frequently verified by later workers. Experiments have shown that under some conditions the presence of earthworms in the soil has a beneficial effect on yields of cultivated crops. E. J. Russell (*J. Agric. Sci.*, 1910, **3**, 246–57) and L. Dreidax (*Arch. Pflanzenbau*, 1931, **7**, 413–67) obtained evidence that the effect of earthworms on crop yields was produced mainly by the decomposition of their dead bodies. The soils they used were reasonably fertile. H. Hopp and C. S. Slater (*Soil Sci.*, 1948, **66**, 421–8), however, using very unproductive subsoil, obtained large increases in yield of grass and clover with soil inoculated with live earthworms as compared with soil to which the same weight of dead earthworms had been added. Where living earthworms were not introduced the growth of clover, grass and weeds was poor and even where manure, lime or fertiliser was added or the soil cultivated, the unfavourable conditions were not eliminated. Where living earthworms were introduced and favourable cover conditions maintained for the over-winter development of earthworms, the vegetation—particularly the clover—grew luxuriantly. Ants produced the same benefits as earthworms. It is pointed out that clover is intolerant of a poor soil structure whereas grass and weeds are not. In a later paper (*J. Agric. Res.*, 1949, **78**, 325-41) similar experiments are reported using various field crops grown in soils with both good and poor structure. In every case dead earthworms added shortly before sowing the crops gave considerable increases in yield, and live earthworms gave still higher yields, the additional increases being large with poor-structured soils and small with good-structured soils. Even when the soils were liberally fertilised, dead earthworms had a marked effect on yield, and the authors conclude that substances of unknown nature are released from the worms' bodies that produce beneficial effects not obtained from commercial fertilisers or the fresh cow dung that was used.

Evidence was obtained that the release of beneficial substances occurs chiefly during the summer when earthworms normally pass through their reproductive period. On the other hand, the effect of living worms on soil structure was greatest during the winter and early spring, and it is suggested that in order to obtain these benefits for agriculture it is necessary to ensure that the worm population is maintained over the winter. By protecting clean-cultivated land with a hay mulch during the winter the earthworm population was increased and the soil structure was improved (*J. Agric. Res.*, 1949, **78**, 347–52).

E. Frei (*Landw. Jahrb. Schweiz*, 1948, **62**, 20–36) found that

inoculation of loose or weakly cohesive soils with earthworms produced a cohesive sponge-like structure in quite a short time. O. Z. Gurianova (*Pochvovedenie*, 1940, No. 4, 99–107) found that earthworms had a greater effect in increasing the aggregation of good-structured soil that had been under lucerne for some time than of pulverised soils that had been growing wheat continuously. R. C. Dawson (*Soil Sci. Soc. Amer. Proc.*, 1948, **12**, 512–6) showed that the stability of the aggregation of earthworm casts was increased when plant material was added to the soil. The casts were very water-stable, but there was no direct relationship between the number of micro-organisms and the formation of water-stable aggregates.

From a study of the greater stability of structure of earthworm casts from a grassland as compared with those from an adjacent cultivated soil, R. J. Swaby (*J. Soil Sci.*, 1950, **1**, 195–7) concluded that binding substances were derived from grass roots during their passage through the worms. Grassland casts contained exceptionally high numbers of bacteria which might have produced the gums glueing the soil particles together. Evidence was obtained that earthworms only improve the structure of soils well supplied with nutritive organic matter which allows the number of intestinal bacteria to multiply and produce structure-forming glues.

Although earthworms constitute the most important single group of animal soil-formers, the combined effects of the rest of the soil fauna are probably as great as, or greater than, those of earthworms. W. Kühnelt (*Bodenkultur*, 1950, **2**, 49–53) points out that the process of plant-residue decomposition consists largely of the residues being eaten by various members of the soil fauna. The pioneers of the process include slugs, wood lice, many kinds of midge, millipedes and caterpillars which in turn are consumed by spiders, beetles, other millipedes and ants. The end products of this animal metabolism are carbon dioxide, water and certain nitrogenous compounds, mainly of the purin and urea groups, which are largely retained in the bodies of the soil fauna and only become available to nitrifying and other bacteria on the death of the animals. It is in the passage of plant residues through the bodies of animals that the materials are comminuted and certain substances, especially nitrogen compounds and cellulose, made available to micro-organisms. The main process of humus formation is effected in the passage of plant material through the digestive tract of soil animals. Material may pass through several animal bodies before it is finally excreted as stable humus.

L. Meyer (*Bodenk. PflErnähr.*, 1943, **29**, 119–39) found that, after

composting straw for two years, about 75 per cent. of the remaining material consisted of the excrement of worms and insects that, as a black crumby material, was quite distinct from the brown straw fragments that had undergone little decomposition. The excrement was in a much more advanced state of humification than were the straw fragments. The carbon-nitrogen ratio in the excrement was 10, and in the rotted straw 18, while the ash content of the excrement was 65 per cent. and of the rotted straw 6·8 per cent. W. Kubiena (*Z. Weltforsch.*, 1943, **10**, 387–410) showed by direct microscopic observation that most of the humus in many soils consists of excrement, and W. Wittich (*Forstarchiv*, 1943, **19**, 1–18) concluded that decomposition of forest litter was effected mainly by the soil fauna. C. H. Bornebusch (*Trans. 4th Internat. Cong. Soil Sci.*, 1950, **1**, 173–84) found that earthworms were the main agents decomposing organic matter in mull (deciduous-forest) soils, and arthropods in mor (coniferous-forest) soils.

H. Franz (*Veröffent. Bundesanst. Alp. Landw. Admont*, 1950, **2**, 1–114) found that the humic matter produced in manure heaps was composed predominantly of faunal excrement, the role of bacteria and fungi in humification being mainly to make the organic matter of the manure available for the nutriment of the lesser fauna. As humification progressed the faunal population of the manure heap approached more and more closely to that of ordinary soils. Judged by the acetyl-bromide test, humic substances were synthesised during the passage of organic matter through the digestive tracts of the small fauna.

H. Franz (*ForschDienst.*, 1941, **11**, 355–68) has investigated the faunal population of cultivated and uncultivated soils. In the latter the greater part of the insect population inhabited the top 3 cm. Nematodes were plentiful down to 20 cm., and faunal life virtually ceased below 25 cm. Populations of similar magnitude, but spread over greater depths, were found in cultivated soil. Franz (*Forsch-Dienst.*, 1942, **13**, 320–33) estimated that there were 750,000 insects, worms, etc. and 20 million nematodes in a square metre (top 10 cm.) of grassland soil. The nematodes are believed to play an important role in the decomposition of cellulosic residues in the soil (H. Franz, *Bodenk. PflErnähr.*, 1943, **32**, 336–51).

M. S. Giliarov (*C. R. Acad. Sci., U.R.S.S.*, 1944, **43**, 267–9) estimated the numbers of insects in the arable layer of cultivated soils to range from 12 to 2000 million. He showed (*Pochvovedenie*, 1949, 574–83) that each of the main soil types of the Crimea has a characteristic fauna. A correlation was found between the amount of humus, the abundance of roots and the number of invertebrates

in each soil horizon. Solonchaks are characterised by the absence of a soil fauna except for certain insects found on non-saline hillocks and closely associated with the vegetation. Solonetses have an insect fauna, with an ephemeral larval stage, developing in the surface, humus-containing horizon. Chestnut soils also have a mainly insect fauna, including phytophages with a long developmental cycle, and facultative saprophages with a short developmental cycle. Chernozems and brown earths show the greatest development of a saprophagous invertebrate fauna which goes into the subsoil in the dry season. The most important representative is the earthworm which is responsible for the even distribution of humus in the chernozem profile, and is much more abundant in the chernozem than in the other soil types.

Studies of insect activity in the tropics have been confined largely to the termite. J. G. Shrikhande and A. K. Pathak (*Curr. Sci.*, 1948, **17**, 327–8) state that termites, ants and earthworms all increase the pH of the soil. G. Milne (*J. Ecol.*, 1947, **35**, 192–265) reported the presence of lime nodules in termite mounds in East Africa, and R. L. Pendleton (*Thai Sci. Bull.*, 1941, **3**, No. 2, 29–53) described the accumulation of calcium carbonate at the base of termite mounds, although they were not near any calcareous deposits and the neighbouring soils were acid. Termites, however, do not appear to increase the availability of plant nutrients (Shrikhande and Pathak, *loc. cit.*). G. ap Griffith (*E. Afric. Agric. J.*, 1938, **4**, 70–1) obtained inconsistent results in comparing the chemical composition of termite mounds and adjacent soils, and A. W. R. Joachim and S. Kandiah (*Trop. Agriculturist*, 1940, **95**, 333–9) found appreciably less organic matter, nitrogen and exchangeable bases in termite mounds. It cannot be said, with the same certainty as with earthworms, that termites, although active soil-formers, have an entirely beneficial effect on the agricultural properties of a soil.

PLANT PHYSIOLOGY. By PROFESSOR WALTER STILES, Sc.D., F.R.S. The University, Birmingham.

PHOTOSYNTHESIS.—An outstanding publication on photosynthesis has been issued by the American Society of Plant Physiologists. This is a monograph entitled *Photosynthesis in Plants* (The Iowa State College Press, Ames, Iowa, 1949), which is edited by J. Franck and W. E. Loomis and which comprises 22 articles written by authorities on the various aspects dealt with in the different articles. After a general introduction by Loomis, photosynthesis under field conditions is dealt with by M. D. Thomas and G. R. Hill. Here the

reader will find much useful information relating to apparatus for measuring the absorption of carbon dioxide by plants growing in the open, as well as actual data of photosynthesis by crop plants. The conclusion is drawn that under field conditions the course of photosynthesis is determined mainly by light intensity. Temperature appears to have practically no effect. Thus temperature coefficients (Q_{10}) for lucerne between 15° and 32° were found to have values of 0·89 to 1·10. It should be noted that these were obtained in experiments in which normal air was employed. It is possible that in an atmosphere with higher concentrations of carbon dioxide temperature may have a more pronounced effect.

A large amount of work on the products of photosynthesis is summarised by J. H. C. Smith, who points out how varied are the substances found in photosynthesising organs. He stresses the difference between two concepts of photosynthesis, an older one according to which water and carbon dioxide combine to-produce carbohydrate and oxygen by means of a photosensitised reaction, and the more modern one according to which carbon dioxide is taken into organic combination and then, through a series of reactions involving the uptake of hydrogen derived from the photochemical decomposition of water, a number of products result.

The structure, composition and development of chloroplasts are reviewed by S. Granick and the functions and properties of the chloroplast pigments by H. H. Strain. It now appears that the chloroplasts of intact cells are saucer-shaped with the concave side towards the vacuole of the cell. Examination of chloroplasts with the electron microscope indicates that the granules observed in chloroplasts first in 1883 by Meyer and called by him " grana " are real morphological units and that a mature spinach chloroplast contains about 40 to 60 of them. The grana appear to be held in a matrix with a refractive index about the same as that of the grana. The grana probably contain the leaf pigments, but the evidence on this is not completely definite. A single granum would contain several million chlorophyll molecules.

Several writers deal with the question of the quantum yield of photosynthesis, that is, the number of molecules of carbon dioxide utilised per energy quantum. The value of 0·25 had been proposed for this by Warburg and a lower value of about 0·1 by Emerson and Lewis. The various writers in the symposium, namely R. Emerson and M. S. Nishimura, W. E. Moore and B. M. Duggar, F. F. Rieke and W. Arnold, all favour the lower value.

Some of the most interesting articles in the symposium deal with the use of radioactive tracers in researches on photosynthesis. The

first of these articles is by M. D. Kamen. With Ruben and Hassid, Kamen was a pioneer in the use of radioactive tracer elements and here he evaluates the work done in the years 1939–41 in view of more recent work. This early work was carried out with the short-lived radioactive C^{11} ; it was not until 1945 that the long-lived isotope C^{14} became readily available. Later work has, however, produced data which are in agreement with the original view of Ruben and Kamen that carbon dioxide is fixed by a dark reaction which involves reversible carboxylation and that this is followed by reduction by means of hydrogen donors produced by photochemical reactions.

A. A. Benson, M. Calvin and a number of collaborators write on C^{14} in photosynthesis. When carbon dioxide containing this isotope is fed to *Chlorella* they find quantities of carboxylic acids and amino-acids are produced in the dark. The proportion of the total amount of carbon fixed which appears as carboxylic acids decreases with increase in the length of a pre-illumination period, while the proportion which appears as amino-acids increases ; thus during a dark period of 5 minutes without pre-illumination the proportion of carboxylic acids was found to be 52 per cent., with a pre-illumination period of 5 minutes it was 21 per cent. and with a pre-illumination period of 120 minutes it was only 11 per cent. The corresponding values of amino-acids were respectively 31, 41 and 74 per cent. Benson and his colleagues from their experimental findings suggest a scheme of the path of carbon in photosynthesis involving a cycle of organic acid transformations, with the production of hexose via the phosphorylation of pyruvic acid. The net result of the suggested cycle of acid transformations is, however, the reduction of two molecules of carbon dioxide to one of acetic acid, the reduction being affected through reducing systems resulting from photochemical action. It should here be mentioned that Calvin has recently announced that phosphoglyceric acid is the first recognisable product of synthesis which contains carbon.

A. H. Brown, E. W. Fager and H. Gaffron also write on the results of experiments with radioactive carbon. They show that, when photosynthesising cells of *Scenedesmus* are exposed for periods not exceeding 40 seconds to $C^{14}O_2$, most of the tracer is found in a water-soluble fraction, and that the material in which the tracer is fixed is not affected by respiration or fermentation. It is, however, transformed on exposure to light, and it would appear to contain a photosensitive intermediate between the primary dark fixation product and the final product of photosynthesis. The fixed tracer appears to be contained in two substances, one containing over 75 per cent. of the tracer. This supposed intermediate is not a

carbohydrate, an amino-acid, a keto-acid, an acid of the metabolic cycle, an aldehyde, keto phenol, alcohol or polyhydroxy acid, nor a phosphate ester of any such substance. The remaining portion of the fixed carbon also does not appear to be held in any of these classes of substances. The supposed intermediate thus appears to be different from the carboxylic acid found as a result of carbon fixation in the dark, and it is suggested by Brown, Fager and Gaffron that the latter may have nothing to do with photosynthesis.

Among other articles in the symposium are one on diffusion through multiperforate septa by J. Verduin, the photochemistry of chlorophyll by R. Livingston, other chlorophyll studies by P. Rothemund, processes accompanying chlorophyll formation by J. H. C. Smith, chlorophyll fluorescence as an energy flowmeter for photosynthesis by E. Katz, the relation of fluorescence of chlorophyll to photosynthesis by J. Franck, the pattern of photosynthesis in *Chlorella* by J. Myers and the comparative biochemistry of photosynthesis by C. B. van Neil.

D. I. Arnon and F. R. Whateley ("Is chloride a co-enzyme of photosynthesis?" *Science*, **110**, 554–6, 1949) have examined the theory put forward earlier by Warburg and Lüttgens that the chloride ion is a co-enzyme essential for photochemical reactions in photosynthesis. This theory is based on the discovery that the capacity for oxygen evolution by isolated chloroplasts of sugar beet and spinach is lost if these are washed several times in water, but that the capacity is completely regained by the addition of cytoplasmic fluid, which is found to contain 0·08N chloride. Moreover, addition of chloride alone as M/150 potassium chloride brings about complete recovery of the power of oxygen evolution. Of a number of other anions used only bromide produces anything approaching the same effect, while all cations tried have no effect.

Now if the theory of Warburg and Lüttgens is correct it means that chlorine is an essential element for photosynthesis and hence for plant nutrition, a view not generally held. Arnon and Whateley have therefore repeated the experiments of Warburg and Lüttgens by growing plants of sugar beet and chard in nutrient solutions free from chloride. The plants grow well but evolution of oxygen by the isolated chloroplasts, which contain no chloride, is feeble, nor is oxygen evolution increased by the addition of cytoplasmic fluid, which also contains no chloride. Addition of chloride or bromide, however, results in the evolution of oxygen in relation to the quantity of oxidant used. These results are thus in line with those of Warburg and Lüttgens.

To explain the fact that chloride or bromide, while unessential

for growth, is nevertheless necessary for oxygen evolution from isolated chloroplasts, Arnon and Whateley suggest that when the cell is broken a cell constituent essential for the photochemical evolution of oxygen by chloroplasts can suffer inactivation by light, but that it can be protected from such inactivation by chloride or bromide. In the intact cell this would be achieved in some other way. In support of this view it is found that, when isolated chloroplast fragments without added chloride are illuminated for 20 minutes before adding the oxidant necessary for the evolution of oxygen, very little oxygen is produced even when chloride is added with the oxidant. But, if chloride is present during the exposure of the chloroplast fragments to light, addition of the oxidant brings about a vigorous evolution of oxygen.

In another contribution dealing with the evolution of oxygen by chloroplast fragments Arnon and Whateley ("Factors influencing oxygen production by illuminating chloroplast fragments," *Arch. Biochem.*, **23**, 141–56, 1949) record that with three oxidants employed, quinone, potassium ferricyanide and phenol indophenol, the theoretical yield of oxygen by the chloroplast fragments on illumination can be obtained. They also find that hydroxylamine, sodium azide and phenylmethane, which are inhibitors of photosynthesis, also inhibit oxygen evolution by chloroplast fragments. This finding can be regarded as supporting the view that the oxygen-releasing mechanism in isolated chloroplast fragments is identical with that in intact photosynthesing cells.

E. K. Gabrielsen ("Threshold value of carbon dioxide concentration in photosynthesis of foliage leaves," *Nature*, **161**, 138, 1948) finds that when leaves of elder are exposed in a closed chamber containing atmospheric air to an incandescent light of an intensity of 10,000 lux, carbon dioxide is absorbed until the concentration of the gas in the chamber falls to 0·0090 volume per cent., after which no more carbon dioxide is absorbed. Moreover, if the concentration of the carbon dioxide in the air in the chamber is initially as low as 0·0024 volume per cent., carbon dioxide is liberated from the leaves until its concentration is about 0·0089 volume per cent. From these observations Gabrielsen draws the conclusion that for photosynthesis there is a threshold value for carbon dioxide concentration which for elder leaves is about 0·0090 volume per cent.

Gabrielsen has also investigated the effect of chlorophyll concentration on photosynthesis ("Effects of different chlorophyll concentrations on photosynthesis in foliage leaves," *Physiologia Plantarum*, **1**, 5–37, 1948). Leaves of the following species and varieties were used : *Populus canadensis* and its variety *aurea* ;

Ulmus carpinifolia and *U. glabra* var. *lutescens* ; *Sambucus nigra* and its variety *aurea*, and *S. canadensis* var. *aurea* ; *Atriplex hortensis* and its variety *chlorina* ; *Triticum sativum* var. Queen Wilhelmina. Thus leaves with very different chlorophyll contents were employed, the chlorophyll content varying from 0·21 mg. per sq. dec. in *Samburus canadensis aurea* to 8·7 mg. per sq. dec. in *Populus canadensis*. The relation between light intensity and rate of photosynthesis was determined for the different leaves. Over the lower range of chlorophyll concentrations increase in chlorophyll content brings about a considerable increase in the rate of photosynthesis, but when a chlorophyll content of 2 mg. per sq. dec. is reached further increase in chlorophyll content has progressively less effect on photosynthesis until, when a content of 4 to 5 mg. per sq. dec. is reached, further increase in chlorophyll concentration has practically no effect on the rate of photosynthesis. Now recent observations on the relation between light absorption and chlorophyll concentration show that this is very similar to that between rate of photosynthesis and chlorophyll concentration, and it would indeed appear that the curve relating maximum energy yield, as measured by photosynthetic activity, to chlorophyll concentration is a biological expression of the influence of chlorophyll concentration on light absorption. The energy yield in green leaves varies apart from their chlorophyll content, being highest in thick sun leaves and lowest in thin shade leaves ; this is related to the greater power of absorption by the thick sun leaves. From an ecological point of view Gabrielsen concludes that chlorophyll content does not have much effect on photosynthesis by foliage leaves. Only in young leaves and in leaves of yellow varieties is the chlorophyll content a factor significantly influencing the rate of photosynthesis, and then only in low light intensities.

The effect of light intensity on photosynthesis of plants growing under natural conditions has been reported on by G. E. Blackman and A. J. Rutter (" Physiological and ecological studies in the analysis of plant environment, III. The interaction between light intensity and mineral nutrient supply in leaf development and in the net assimilation rate of the bluebell (*Scilla non-scripta*)," *Ann. Bot.*, N.S., **11**, 1–26, 1948). They find that over the range full daylight to 0·11 full daylight the net assimilation rate of the bluebell is directly proportional to the logarithm of the light intensity. The same relationship is found to hold also for the sunflower. It is therefore supposed that even in full daylight net assimilation rate is controlled by the duration and intensity of daylight.

ENTOMOLOGY. By A. D. LEES, M.A., Ph.D., Agricultural Research Council, Unit of Insect Physiology, Cambridge.

THE PHYSIOLOGY OF DIAPAUSE.—The nature of a process which operates in the growing organism by "dissociating the morphogenetic mechanism from the mechanism of maintenance" (Carroll Williams) is undoubtedly of fundamental biological interest. But the condition of arrested development, known in insects as a state of diapause, is also interesting for other reasons. Few would deny the adaptive value of diapause in enabling the insect to survive unfavourable cold or dry conditions and times of food scarcity. From this point of view the condition is an essential device for adjusting the life cycle to the environment.

The capacity to enter diapause is, of course, inherited. But in many insects diapause is facultative and is not evoked unless the appropriate external conditions are encountered. Once initiated, dormancy as a rule persists long after the factors which led to its inception have ceased to operate. And it is finally eliminated by the action of other agencies, often of a quite different nature. This type of control would be expected to give considerable flexibility in the life cycle. For example, the number of annual generations in a rapidly reproducing species may be considerably increased if climatic or weather conditions are particularly favourable.

In contrast, it may be biologically advantageous for some species, such as those requiring a long growth period, to have the onset of diapause fixed in each generation. Diapause is then obligate and occurs regardless of the external conditions. (Or it may be that diapause is induced by such a wide range of conditions that it is difficult to recognise the "factors" as separate entities.) Insects in this category usually pass through only one generation annually and their life cycle is adjusted to the seasons by the timing of the release from diapause, which in most instances remains under the influence of climatic agencies.

Recent work on the relative dependence of diapause on external conditions may now be considered. In all cases the occurrence of a true diapause, whether facultative or obligate, implies that the insect possesses the appropriate mechanism, hormonal or otherwise, for interrupting the normal processes of growth. The substantial advances in our knowledge of these mechanisms will be outlined subsequently.

Temperature has been shown to be an important stimulus in controlling both the onset and the elimination of diapause in *Eurydema ornatum* (C. Bonnemaison, *C.R. Acad. Sci.*, 1948, **227**,

985, 1052). This Pentatomid bug enters diapause in midsummer as the adult and overwinters without feeding or ovipositing until the following spring. Diapause can be elicited experimentally if the third-stage nymph is subjected to a fall in temperature. Females in a state of diapause can be induced to feed and lay eggs by exposing them to alternating medium and low temperatures.

Although it is very well known that *light* (day length) plays an important role in controlling the reproductive cycle in many mammals and birds, surprisingly little attention has been given to the possible relations of light and diapause in insects. This subject has recently acquired a new perspective with the publication of R. C. Dickson's work on the oriental fruit moth *Grapholitha molesta* (*Ann. ent. Soc. Amer.*, 1949, **42**, 511). This insect feeds on the leaves and twigs of rosaceous plants, particularly peach. There are from two to seven annual generations in the United States, the number depending on the geographical situation. As the fully grown larva enters diapause in late summer considerably before the weather becomes cold, there is little indication from the behaviour in the field that low temperatures are a predisposing factor.

The induction of diapause is primarily a response to the photoperiod. When reared under controlled conditions, a daily photoperiod of 14 hours or longer produced exceedingly few diapausing larvæ, while with 13 or 12 hours of light almost every larva entered diapause. With shorter photoperiods, and in complete darkness, non-diapausing larvæ again appeared in numbers. Temperature also has a considerable influence. The above relationship is dominant only at medium (21–26° C.) temperatures. With either higher (30° C.) or lower (12° C.) temperatures the effect of a 12-hour photoperiod is much smaller.

Wavelengths in the blue-green region of the spectrum were the most effective in inducing diapause; ultra-violet and infra-red radiation was without effect. The threshold intensity of illumination required to induce diapause—about 3 foot-candles—is at first sight surprisingly low, for in these experiments the larvæ were feeding inside immature apples. However, Dickson points out that the latter are appreciably translucent. Indeed, although direct evidence cannot be provided here, it is probable that the insect is influenced by the photoperiod directly and not indirectly through the plant.

Extensive observations on the induction of diapause when the total light-dark cycle is longer or shorter than 24 hours showed that the mode of action of light must be complex. The absolute duration of both the light and the dark periods are significant and must fall

within narrow limits. No insects entered diapause when the total cycle was shorter than 20 or longer than 26 hours.

The diapause behaviour of the codling moth *Cydia pomonella* proved to be very similar to that of its close relative the oriental fruit moth. But among the other insects tested by Dickson, *Lucilia sericata* and the vegetable weevil *Listroderes obliquus* were indifferent to light.

A photoperiodic response of a comparable nature has recently been demonstrated in the tomato moth *Diataraxia oleracea* by M. J. Way, B. Hopkins and P. M. Smith (*Nature, Lond.*, 1949, **164**, 615). In normal daylight the pupæ tend to enter diapause in spring and autumn but not in midsummer. Experiment showed that diapause seldom supervened when the photoperiod was 16 hours or longer. With shorter daylengths, and indeed in this case in total darkness, nearly all the insects entered diapause. Using a long photoperiod, continuously breeding populations could be maintained indefinitely in the laboratory.

The incidence of diapause in the cabbage butterfly *Pieris brassicæ* and the cabbage moth *Mamestra brassicæ* could also be much reduced by growing the larvæ under long day conditions. But in the latter insect diapause is evidently in some degree obligate, since it invariably supervened after three generations, irrespective of the external conditions.

The onset of diapause in another phytophagous insect, the browntail moth *Euproctis phæorrhæa*, is governed by the *nutrition*. The eggs hatch outside in July, the young larvæ spinning a communal web in which they feed during the summer months. They enter diapause in September as second or third instar larvæ. P. Grison (*C.R. Acad. Sci.*, 1947, **225**, 1089) has reported that larvæ fed in late summer on the youngest apple foliage available outside at this time of year develop without diapause. But diapause occurred in the normal manner if the food consisted of the oldest leaves. This relationship was maintained even when the larvæ were reared under conditions which, in winter, were effective in eliminating diapause, namely a high temperature (25° C.) and a saturated atmosphere.

A further example of facultative diapause is afforded by the pink bollworm of cotton (*Pectinophora gossypiella*). Here the *moisture content* of the boll is generally agreed to be the principal determining agency. F. A. Squire (*Bull. ent. Res.*, 1940, **30**, 475) concluded that the proportion of fully grown larvæ entering diapause was a simple function of the age of the boll, which loses water and gains in oil as it ripens. L. C. Fife (*U.S. Dept. Agric. Tech. Bull.*, No. 977, 1949) decided that any factor limiting the moisture content of the boll,

such as low humidity and rainfall, high temperatures, etc., tends to induce diapause. The dormant state is broken by contact with moisture or even exposure to a high humidity.

Maternal influences may sometimes control the induction of diapause more completely than the immediate external stimuli. Some examples have been described by F. J. Simmonds (*Phil. Trans. B.*, 1948, **233**, 385). The Pteromalid *Spalangia drosophilæ*, which can be reared as an ectoparasite on *Drosophila* puparia, enters diapause facultatively as the fully grown larva. Dormant larvæ are encountered throughout the season in the field, so that the occurrence of diapause is not easily correlated with the prevailing meteorological conditions. The behaviour in this instance was found to be determined largely by the age of the mother, the incidence of diapause among the offspring tending to rise with age. Other factors, notably temperature, exerted some effect both through the mother and, more immediately, on the growing larvæ themselves. Simmonds believes, however, that the primary agency in evoking diapause is the level of metabolic activity in the egg-laying insect.

In the Colorado beetle *Leptinotarsa decemlineata* diapause of an apparently obligate type is encountered. Although the tendency of the beetles to enter the soil during the summer or autumn has sometimes been held to be due to immediate dry or cold conditions, P. Grison (*C.R. Acad. Sci.*, 1944, **218**, 342) considers that a true diapause is involved. Three successive generations of these insects could be reared in the laboratory, but an increasing proportion entered diapause and the whole of the small third generation did so. An unusual feature in this insect is that the termination of the state of diapause does not appear to be hastened by low temperatures.

In some insects with an obligate diapause there are both uni- and multivoltine strains. Individuals belonging to the first enter diapause at every generation, those of the second only after two or more generations. The strains of the European cornborer *Pyrausta nubilalis* in North America and Canada afford an interesting example. In New England the insect is represented by a multiple generation strain, while in Ohio and the Lake States both multi- and univoltine strains occur side by side and interbreed. This behaviour is determined genetically. K. D. Arbuthnot (*U.S. Dept. Agric. Tech. Bull.*, No. 869, 1944) has shown that the New England strain is homozygous for multiple generations. He was also able to select from the mixed Ohio population a strain homozygous for univoltinism ; but it proved more difficult to isolate a line homozygous for multivoltinism, some diapausing individuals occurring at every generation in all the selected lines.

There are other physiological differences between the cornborer strains. The univoltine strain develops more slowly and the flight period is later in the season. Adults show some disinclination to mate with individuals of the opposing strain. The food preferences are also markedly different. The multivoltine New England strain attacks over 200 plant species, while the univoltine strain is usually confined to one host plant, maize.

The seasonal history of the cornborer in Ohio has been described by C. R. Neiswander (*J. econ. Ent.*, 1947, **40**, 407). During the first few years after its introduction only one annual generation was seen ; a partial second generation appeared in 1937 and by 1945 the multivoltine behaviour was fully established. There were corresponding changes in the flight period, etc. G. Wishart (*Canad. Ent.*, 1947, **79**, 81) has also examined the changes in the cornborer population of western Ontario, where a similar trend has been observed. As the bivoltine strain becomes less abundant to the north and west, it is possible that its spread is checked by adverse meteorological conditions. An interesting fact which suggests an independent origin for the multivoltine New England and Ontario strains is that the latter is almost entirely monophagous.

Mechanisms of Diapause.—In the search for the causal mechanisms of diapause the egg clearly presents the greatest technical difficulties. Studies by Bodine on the grasshopper *Melanoplus differentialis* led him to postulate the existence of an inhibitory factor which was present in the egg when laid and which increased in concentration until development was arrested. Exposure to cold was then thought to destroy the diapause factor rapidly, whereas uniformly high temperatures resulted in its slow decay and the ultimate release from diapause.

An extensive analysis of the role of temperature in eliminating diapause in the eggs of the grasshopper *Austroicetes cruciata* led H. G. Andrewartha (*Bull. ent. Res.*, 1943, **34**, 1) to offer an entirely different explanation. Exposure to cold was needed to bring diapause to a close but this was ineffective, and indeed resulted in the appearance of abnormal embryos, unless a particular stage of embryonic growth had been reached. The appearance of the embryos suggested that the action of low temperatures was to modify the yolk, which subsequently became more suitable for nourishing the embryo and less liable to obstruct the movements of the embryo in blastokinesis.

E. H. Slifer (*J. exp. Zool.*, 1946, **102**, 333), also working with *Melanoplus*, has since shown that diapause is readily broken when the egg is immersed for 30 minutes in xylol or similar solvents.

As in other grasshopper eggs, the water exchanges take place only through the hydropyle; and the resumption of embryonic growth after diapause is invariably accompanied by a considerable water uptake. Solvents remove a layer of wax, possibly secreted by the hydropyle cells prior to diapause, and thus permit water to enter. (The properties of the isolated wax are described in Slifer, *Discussions of the Faraday Soc.*, 1948, No. 3, 183.) This evidence suggests that the state of diapause in this egg is associated with lack of water rather than with the presence of any specific inhibitory factor. Meanwhile, the mode of action of temperature in relation to this scheme remains to be resolved.

The mechanism of diapause has also been discussed by R. W. Salt (*Canad. J. Res. D.*, 1947, 25, 66) in a paper on the wheat stem sawfly *Cephus cinctus*. Although the diapause of the fully grown larva can be brought to an end by cold, the condition may be reinstated if the insect is desiccated or exposed to high temperatures. This may actually occur in nature and result in a two-year life cycle. Salt points out that these results can be explained by assuming the presence of two factors of an inhibitory nature, their elimination being dependent on chemical reactions with different temperature coefficients.

Our present knowledge of the endocrinology of diapause is due almost exclusively to the researches of C. M. Williams on the giant silkworm *Platysamia cynthia*. This insect enters diapause immediately after pupation, the condition being maintained for at least 5 months at room temperatures. Diapause is broken by exposure to a low (3–5° C.) temperature for about 6 weeks.

The dormancy of the pupa in diapause could be overcome by joining it surgically with a previously chilled, and therefore activated, pupa. Therefore, in this insect at least, diapause is shown to result from the lack of some essential factor and not from the presence of inhibitors.

The hormone responsible was found to emanate from the brain itself (*Biol. Bull.*, 1946, 90, 234). Thus pupæ with the brain removed remained alive but in diapause for as long as two years. The brains from chilled pupæ also provoked imaginal development when implanted into normal pupæ in diapause. Cold seems to render the brain competent to release its factor after the insect is returned to the higher temperature.

The activity of the brain proved to be confined to two groups of large neurosecretory cells lying in the cerebral lobe (Williams, *Growth Symposium*, 1948a, 12, 61). Both are necessary for the correct functioning of the brain; neither is effective if implanted

separately or even if cut apart. These cells may well be homologous with the similar cells that are known to control moulting in *Rhodnius* and also pupation in many Lepidoptera. Williams observes that the latter are all species without a diapause ; in these the brain may perhaps act precociously, initiating both pupation and imaginal development simultaneously. Whereas in *Platysamia* the dual functions seem to be separated in time.

The brain factor does not stimulate the tissues directly. When brainless diapausing pupæ were divided transversely and chilled brains implanted in the respective halves, the anterior fragment developed while the isolated abdomen remained in diapause (*Biol. Bull.*, 1947, **93**, 89). Transactions at different levels showed that this differentiation centre lay within the thorax. The only organs capable of initiating the development of an isolated abdomen (when implanted with a chilled brain) proved to be the prothoracic glands. Further experiments designed to study their interaction showed that the brain exerted a trigger-like action upon the prothoracic glands ; once stimulated the latter could activate the tissues directly, without the further intervention of the brain.

The anatomy of the prothoracic glands in *Platysamia* has been described in a separate paper (*Biol. Bull.*, 1948b, **95**, 60) which also contains a discussion on the significance of a thoracic differentiation centre in controlling post-embryonic development in other insects.

The prothoracic glands were well described and figured by Lyonet in 1762 but were lost sight of for many years subsequently (Williams, *Biol. Bull.*, 1949, **97**, 111). Their significance as endocrine organs was discovered in 1941 by S. Fukuda who showed in *Bombyx mori* (which lacks the pupal diapause) that the glands, when implanted into the ligatured pupal abdomen, had the power of provoking further development. The morphology of the prothoracic glands in the larvæ of a number of Lepidoptera has recently been studied by H. T. Lee (*Ann. ent. Soc. Amer.*, 1948, **41**, 200). In all cases they take the form of irregular bands of glandular tissue lying near the prothoracic spiracle.

The nature of the brain factor is not known. It cannot be demonstrated by injecting the blood from chilled pupæ ; it is possible indeed that this factor travels in the tissues. On the other hand, the prothoracic gland hormone can be detected in the blood by a method devised by E. L. Schmidt and C. M. Williams (*Anat. Rec.*, 1949, **105**, 487). These authors found that spermatocytes from the testes of dormant pupæ rapidly developed into spermatids when cultured in hanging drop preparations of the insect's own blood. And the blood was invariably active in this respect during

periods of known prothoracic gland activity. By the evidence of this test, the hormone is present at pupation, disappears entirely during diapause, but reappears as imaginal differentiation begins.

The cyanide insensitivity of pupæ in diapause and their increasing sensitivity as growth and differentiation begins, has suggested that the cytochrome system was involved (Williams, 1948a, *loc. cit.*). The results of blood analyses showed that cytochrome oxidase increases greatly in concentration during brain activity, but diminishes after the prothoracic glands have been stimulated (when the brain becomes inactive). The titre of cytochrome C, which is negligible during diapause, rises steadily as the prothoracic gland activity develops. Evidently the cytochrome system is broken down during diapause and is subsequently resynthesised. While not excluding the possibility that this may be secondary, Williams considers that the absence of the cytochrome system may be the " biochemical defect " which is diapause.

Some preliminary results of an enquiry into the hormonal control of diapause in the cricket *Gryllus campestris* have been given by R. Sellier (*C.R. Acad. Sci.*, 1949, **228**, 2055). This species passes through ten nymphal instars, but the ninth is exceptionally prolonged and the insect itself shows a very decided inactivity. This condition, which in these respects resembles a state of diapause, could be eliminated by implanting the brain from donors that were either younger or older than the diapausing hosts. There is also an association between the duration of the ninth instar and wing production, for macropterous individuals appeared when diapause was cut short in this manner.

NOTES

Pollen in Relation to Beekeeping in New Zealand* (F. N. H.)

A study of the different kinds of pollen found in honey and in bee loads (the pollen baskets of hive bees) has been carried out in the Pongakawa district of New Zealand. The local bee pasturage consisted of a mixture of indigenous plants, especially of " manuka " (*Leptospermum scoparium*) and " rewarewa " (*Knightia excelsa*) and of introduced plants, such as clovers, weeds and cultivated plants. Some 200 species (listed) were known or observed to be visited by honey bees in the area. An interesting fact brought to light, was that some of the pollens commonly found in bee loads, such as that of the " tree lupin " (*Lupinus arboreus*), were not found at all in the honey, which suggests that such plants may be worked by bees entirely for pollen and not for nectar. It is to be hoped it will be possible to continue or extend this sort of work in New Zealand.

Miscellanea

The honours list published on the occasion of H.M. the King's birthday included the following scientists and others associated with scientific work : *Baron :* Dr. E. W. Hives, managing director of Rolls Royce, Ltd. *K.C.B. :* Sir Ben Lockspeiser, secretary to the Committee of the Privy Council for Scientific and Industrial Research. *K.B.E. :* Prof. D. B. Copland, vice-chancellor of the Australian National University, Canberra ; Prof. N. Hamilton Fairley, for services to tropical medicine. *Knights :* Dr. A. N. Drury, director of the Lister Institute of Preventive Medicine ; Prof. G. Jefferson, professor of neuro-surgery, University of Manchester ; Mr. N. B. Kinnear, formerly director of the British Museum (Natural History) ; Dr. J. I. Orme Masson, vice-chancellor of the University of Sheffield ; Dr. J. E. Myers, principal of the Manchester College of· Technology ; Prof. J. C. Spence, professor of child health, University

of Durham. *C.B. :* Mr. E. H. E. Havelock, secretary of the Development Commission, and recently administrative secretary of the Agricultural Research Council ; Mr. C. K. Johnstone-Burt, principal deputy civil engineer-in-chief, Admiralty. *C.M.G. :* Dr. J. Carmichael, member of the Colonial Advisory Council on Agriculture, Animal Health and Forestry ; Mr. B. J. Hartley, director of agriculture, Aden. *C.B.E. :* Dr. A. J. Amor, principal medical officer, Imperial Chemical Industries, Ltd. ; Mr. R. F. Fowler, for services as a chief statistician, Cabinet Office ; Mr. E. Green, general secretary Workers' Educational Association ; Mr. G. H. Grigg, for services to agriculture (New Zealand) ; Dr. J. Jackson, H.M. Astronomer, Cape of Good Hope ; Prof. T. J. Jenkin, director of the Welsh Plant Breeding Station, Aberystwyth ; Major-General S. W. Joslin, late of the Corps of Royal Electrical and Mechanical Engineers ; Dr. Harold King, formerly head of the Chemistry Division, National Institute for Medical Research ; Mr. W. B. Mercer, provincial director, National Agricultural Advisory Service ; Dr. J. R. K. Paterson, director of the Holt Radium Institute, Manchester ; Capt C. R. S. Pitman, formerly game warden, Uganda ; Capt. J. L. Pritchard, secretary of the Royal Aeronautical Society ; Mr. A. G. Ramsey, chief mechanical and electrical engineer, Ministry of Works ; Mr. T. Rowntree, director of aeronautical inspection, Ministry of Supply ; Mr. C. A. Spencer, deputy chief scientific officer, Department of Scientific and Industrial Research ; Prof. O. G. Sutton, professor of mathematical physics, Military College of Science ; Prof. H. H. Swinnerton, emeritus professor of geology in the University of Nottingham, and chairman of the University of Nottingham Joint Recruiting Board ; Dr. A. J. Turner, director of the Linen Industry Research Association ; Colonel B. Ungerson, late of the Royal Army Educational Corps ; Mr. G. M. Wright, engineer-in-chief, Marconi's Wireless Telegraph Co. *I.S.O. :* Mr. L. S. Davis, Government chemist, Trinidad ; Mr. C. A. Leembruggen, formerly assistant director of surveys, Fiji ; Mr. G. H. Mackey, principal examiner, Patent Office and Industrial Property Department, Board of Trade ; Capt. A. E. W. Nesbitt, surveyor, Gold Coast.

Dr. W. S. Adams, Prof. Carl F. Cori, Prof. E. Fermi and Prof. Carl Skottsberg have been elected foreign members of the Royal Society. Dr. G. M. Trevelyan, master of Trinity College, Cambridge, has been elected a Fellow of the Royal Society under the statute which provides for the election of persons who either have rendered conspicuous service to the cause of science or are such that their election would be of signal benefit to the Society.

Sir John Cockcroft, Prof. P. A. M. Dirac and Prof. R. A. Peters

are among those elected to be foreign honorary members of the American Academy of Arts and Sciences.

The Gold Medal for 1950 of the Royal Astronomical Society has been awarded to Prof. Joel Stebbins, of the Lick Observatory, University of California, for his development of physical methods in astronomical photometry and for the results obtained by the use of those methods.

The Royal Aeronautical Society's Gold Medal has been awarded to Sir Geoffrey de Havilland, for his outstanding work in the field of aviation.

The gold Albert Medal of the Royal Society of Arts for 1950 has been awarded to Sir Edward Appleton, principal and vice-chancellor of the University of Edinburgh, " for outstanding services to science and industrial research."

Other medals awarded include : the fifth annual Holweck Prize and Medal to M. P. Jacquinot, of the Faculty of Science of the University of Paris ; the Gold Medal of the Institution of Mining and Metallurgy to Mr. Robert Annan, past-president of the Institution and chairman of New Consolidated Gold Fields, Ltd., for his distinguished services to the mining industry ; the Warner Medal of the Textile Institute to Mr. L. H. C. Tippett, head of the Mechanical Processing Division of the British Cotton Industry Research Association.

Dr. W. Hume-Rothery, lecturer in metallurgical chemistry in the University of Oxford, has received the Bakhuis Roozeboom Medal of the Royal Netherlands Academy of Sciences, which is awarded once in every four or five years for fundamental work in the field of phase-theory. Prof. F. E. Simon, professor of thermodynamics in the University of Oxford, has been awarded the Kamerlingh Onnes Gold Medal of the Netherlands Society for Refrigeration, in recognition of his contributions to refrigeration techniques at very low temperatures.

Sir Henry Tizard has asked to be relieved of part of his responsibilities as scientific adviser to the Minister of Defence, and Sir Frederick Brundrett, chief of the Royal Naval Scientific Service, has been appointed deputy scientific adviser to the Minister of Defence. Mr. W. R. Cook, director of physical research, Admiralty, has been appointed to succeed Sir Frederick Brundrett.

Prof. W. J. Pugh, professor of geology in the University of Manchester, is to succeed Dr. W. F. P. McLintock as director of the Geological Survey of Great Britain.

Dr. F. Sherwood Taylor, who has been since 1940 curator of

the Museum of the History of Science at Oxford, has been appointed Director of the Science Museum, South Kensington, in succession to the late Dr. H. Shaw.

We have noted with great regret the announcements of the death of the following scientific workers during the quarter : Prof. A. B. Appleton, emeritus professor of anatomy at St. Thomas's Hospital, University of London ; Prof. B. P. Babkin, F.R.S., formerly professor of physiology at McGill University ; Mr. F. F. R. Channer, C.I.E., O.B.E., formerly chief conservator of forests, India ; Mr. M J. B. Davy, keeper of the Department of Air and Water Transport, Science Museum ; Admiral Sir Mostyn Field, K.C.B., F.R.S., hydrographer of the Navy during 1904–9 ; Mr. V. K. Maitland, C S.I., formerly chief conservator of forests, Central Provinces, India ; Mr. H. G. Maurice, C.B., president of the Zoological Society of London, 1942–48 ; Mr. G. H. Nash, C.B.E., a former director of Standard Telephones and Cables, Ltd., known for his work on the seismophone and the hydrophone ; Prof. G. W. Robinson, C.B.E., F.R S., professor of agricultural chemistry in the University College of North Wales, Bangor ; Mr. J. B. Scrivenor, I.S.O., formerly director of the Geological Survey, Federated Malay States; Dr. H. Shaw, director of the Science Museum, South Kensington.

At the beginning of this year the National Physical Laboratory of India was opened in Delhi by Sardar Vallabhbhai Patel, Deputy Prime Minister of India. This is the second of eleven projected National Laboratories to be built, and it owes its inception to Sir Shanti Bhatnagar, Director of Scientific and Industrial Research, who put forward recommendations for the laboratory in 1941. Physical research in India has been steadily increasing during the present century, and this growth has been accelerated by the development of research facilities in Universities, Government Scientific Departments and Research Institutions. In the last decade the Raman Research Institute at Bangalore and the Tata Institute of Fundamental Research at Bombay were founded.

The director of the new laboratory is Dr. K. S. Krishnan, and the work will be carried out through the following nine divisions : Weights and Measures, Applied Mechanics and Materials, Heat and Power, Optics, Electricity, Electronics and Sound, Industrial Physics, Hydraulic Research and Analytical Chemistry.

In 1949 the Association of British Chemical Manufacturers prepared a Report on the Chemical Industry, and, at the request of the

President of the Board of Trade, a chart was included setting out the principal products of the chemical industry and showing how the starting raw materials are further treated and made into final products for other industries. As there has been a considerable demand for this chart from chemists both in the academic world and in industry, it has been reprinted and can be obtained from the Association at 166, Piccadilly, London, W.1. The price is 1s., post free, and cash must accompany the order.

We have received the first issue of a new quarterly journal entitled *The British Journal for the Philosophy of Science*. The general editor is Dr. A. C. Crombie, who is the Hon. Secretary of the Philosophy of Science Group, British Society for the History of Science, and the committee of this group is also the managing committee of the new journal. Dr. Crombie is supported by a strong editorial board and, judging by the first issue, there should be a definite future for this new publication. The first number contains articles on " A Theory of Measurement " by Prof. H. Dingle, " Critical Epochs in the Development of the Theory of Science " by Prof. E. W. Beth, " Descartes and the Body-Mind Problem in Physiology " by Dr. M. H. Pirenne, and " Metaphysical Interpretations of Science, Part I " by Philipp Frank. The annual subscription is 30s. per annum or 7s. 6d. per issue. The publishers are Thomas Nelson & Sons, Ltd., and orders can be sent direct to them or to any bookseller.

Since August the Library and Information Department of the British Scientific Instrument Research Association has joined the Laboratories of the Association at " Sira," Southill, Elmstead Woods, Chislehurst, Kent. Visitors to the Library are welcomed. The nearest station—some five minutes' walk from the house—is Elmstead Woods on the Orpington and Sevenoaks line from Charing Cross, Waterloo or London Bridge.

ESSAY REVIEWS

COMPARATIVE BIOCHEMISTRY. By ERNEST BALDWIN, Ph D.,
Professor of Biochemistry in the University of London, University
College. Being a Review of **Biochemical Evolution**, by MARCEL
FLORKIN, edited, translated and enlarged by SERGIUS MORGULIS.
[Pp viii + 157, with 25 figures.] (New York : Academic Press, Inc.,
1949 $4 00)

THE publication of a new book concerned with the comparative side
of biochemistry is necessarily an important event for, since the
appearance in 1903 of Otto von Furth's *Vergleichende Physiologie
der niederen Tiere*, no attempt has been made to collect into a unified
whole the widely scattered papers that compose the literature of
comparative biochemistry. There have been many textbooks of
comparative physiology, but of these not even Winterstein's
voluminous *Handbuch der vergleichenden Physiologie*, which was
published in serial parts over the period 1910–14 and occupies some
20 inches of shelf space, contains much that is of value to the
biochemist The chemical matter to be found in such books has
usually been incorporated in a completely uncritical fashion so that,
except as a source of references to early and often very obscure
papers, they are virtually useless.

It is in any case true that much early comparative work is of
little but historical interest today. Even a quarter of a century
ago, biochemistry was mainly concerned with problems of clinical
or economic importance. Such fragmentary data of a comparative
kind as had been recorded were largely unreliable and were in many
cases of the sort that appear in the literature only because they
are easy to make and put on record. Already the work of Kruken-
berg, of which Biedermann wrote " Strengste Kritik scheint unter
allen Umständen geboten," and that of Griffiths, of whose observa-
tions remarkably few have ever found confirmation, had combined
to give comparative biochemistry an unenviable start. The ready
endowment of research likely to have a more or less immediate
bearing upon clinical or economic problems was seldom extended
to work on the biochemistry of worms or starfishes, and the bio-
chemist usually found himself tied to the pursuit of more " useful "

and therefore more profitable problems. Thus the field was left open to comparative physiologists who, as representatives of longer-established branches of biological enquiry, found more generous and more ready endowment. Many of their excursions into the field were brilliantly successful as, for instance, were those of such men as Ray Lankester, who brought the new and elegant method of spectroscopy to the study of animal pigments and pigmentation. Many other excursions, on the other hand, served only to add to an existing confusion and to disperse still further an already diffuse literature. As an instance we may mention the abundant early work on the digestive enzymes of invertebrates. Early work in this direction was already foredoomed, even at the hands of competent, trained biochemists because, as J. B. S. Haldane has pointed out, studies on enzymes were " at the mercy of unanalysable changes in the environmental conditions until Sörensen pointed out the dependence of enzyme activity upon pH." Bearing in mind the fact that Sörensen's observations were published as late as 1909 and took some years to penetrate into the less strictly biochemical literature, it is hardly to have been expected that workers with little or no biochemical training could succeed in solving problems of a distinctively biochemical nature, which even a trained biochemist could not properly have dealt with at the time. In this, as in many other directions, comparative biochemistry had to wait for advances in the parent subject, and, although at the present time biochemical thought and technique alike have reached high standards of specialisation and many problems of a comparative kind have been laid open to biochemical investigation, many others in the same field still await the development of new and perhaps even more specialised methods and concepts.

That the evolution of form and function must have a molecular basis cannot today be seriously doubted, but so seriously and for so many years has comparative biochemistry been neglected that the experimental data available even today are isolated, usually unconfirmed and widely scattered throughout the whole field of biological literature. Indeed, as Needham and Needham pointed out almost twenty years ago, " If comparative biochemistry hitherto has presented the appearance of an arbitrary mass of unrelated facts, it is precisely because it has not been comparative enough." The general position has, however, improved somewhat in recent years and there now exists a considerable number of review articles, necessarily restricted in scope yet covering certain specialised aspects of the field thoroughly and critically ; but the synthesis of the whole literature into a single book has still not been attempted. The

reviewer's *Introduction to Comparative Biochemistry*, now in its third edition, first appeared in 1937 and remained alone without companion or rival until Marcel Florkin's *L'Évolution Biochimique* made its first appearance in 1944. From the original French edition an English translation has now been prepared, edited and expanded by Dr. Sergius Morgulis of the University of Nebraska. the highly

Bearing in mind the general state of the subject and hat to write diffuse nature of its literature, it will be clear enough t classification a book in support of his thesis, that " evolution and the int," would of animals can be considered from a biochemical viewpo in arduous have been at any time and under any circumstances a m- ofessor undertaking. The more praise is due, therefore, to Pr van Florkin, whose book was written in Belgium under German occupation.

To write a book that is read and escape without criticism is the lot of very few authors, and the reviewer would point out that much of the criticism here levelled at *L'Évolution Biochimique* is directed not so much at the book and its author as at the present state of the subject with which they deal. Lack of continuity is inevitable in any book that treats of material which itself consists largely of " an arbitrary mass of unrelated facts," but there is in the reviewer s opinion more than an irreducible minimum of discontinuity in the text, so that reading becomes a task rather than a pleasure, albeit the task is well worth the accomplishment.

Professor Florkin begins with evidence pointing to the existence of some kind of common and fundamental chemical ground-plan, which underlies the immense wealth and diversity of size, shape, structure, habit and so on displayed in the animal kingdom. Here, as elsewhere throughout the book, the available evidence is striking enough, yet full of lacunæ. Inconclusive though it must necessarily be, therefore, the evidence points every time to the existence of some fundamental and common pattern and, even if approached in a spirit of critical scepticism, achieves a considerable measure of conviction.

That some such basic design corresponds to reality is not, of course, a new idea, any more than the idea of evolution was wholly new when it was formulated by Darwin. Indeed, such an idea has been tacitly assumed and accepted, at any rate as a working hypothesis, by a number of leaders of biochemical thought. It is particularly clearly implied in the following words, written by the late Gowland Hopkins in 1937 : " I venture to think," he wrote, " that productive thought in biochemistry in particular calls for the widest possible survey of life's manifestations. One of its ultimate

tasks is to decide on what, from the chemical standpoint, is essential for these manifestations, as distinct from what is secondary and specific."

Professor Florkin's second chapter deals no longer with resemblances but with differences ; differences which would appear to be " secondary and specific "—new chemical edifices, probably of adaptive significance, erected upon the common, fundamental ground-work. There is, of course, no lack of evidence of biochemical differences between different groups of animals, and even between morphologically similar species. Differences of this kind are hardly unexpected, but what has always seemed to the reviewer to be particularly striking is not the fact that differences do indeed exist, but rather that there are not more of them. Indeed, the fact that they are not more extensive and more numerous seems to be a weighty if somewhat indirect argument in favour of the existence of a fundamental ground-plan of some kind.

Professor Florkin goes on to trace the evolution of biochemical systems in the animal kingdom, drawing attention first of all to the existence, in different animal groups at different levels in the animal kingdom, of analogous phenomena, such as respiratory carriers of oxygen, respiratory catalysts, phosphagens, osmotically active ions and so on. From this he passes to a study of the evolution of the respiratory function of the blood, of the digestion and digestive enzymes. His sections on the evolution of nitrogen metabolism in relation to the environment are particularly striking and attractive, largely, perhaps, because there is here a field that has been particularly thoroughly explored.

In all, three chapters are devoted to three aspects of these topics under the headings of " L'Évolution des constituants biochimiques," " Systèmes biochimiques à évolution orthogénétique " and " Adaptations biochimiques." Each topic appears three times, once under each of these headings. By arranging his material in this manner the author has, in the opinion of the reviewer, made his reader's task unnecessarily exhausting, for it is necessary to jump from topic to topic several times over in a context that is already disjointed enough. To achieve any sort of continuity would have been difficult with the experimental material available and it is unfortunate indeed that here, where by a more judicious arrangement of the text far more continuity might easily have been achieved, it has in fact nearly disappeared altogether. However, at second reading it proved possible, by selecting the related sections from the three successive chapters and reading them as a sequence, to facilitate the process of reading very considerably, and the reviewer would

recommend this procedure to Professor Florkin's readers. Possit the author would consider a corresponding re-arrangement of the material in his next edition.

In Chapter VI (" Caractères systématiques ") the author focuses attention, in considerable detail, upon the biochemical features which characterise different animal phyla. There is here a mass of information, drawn from many branches of biochemistry, and the chapter achieves a noteworthy synthesis of great comparative value. But most important of all is the last chapter, entitled " Perspectives," in which attention is drawn to fundamental biological problems rather than to points of detail. There are sections on biochemistry in relation to morphology, the mechanisms of biochemical evolution biochemical recapitulation in ontogenesis, the problem of the reve sibility or irreversibility of biochemical evolution, and biochemistry in relation to phylogenesis. Here there is much that is profound and much that every biologist, be he biochemist, physiologist or morphologist, should read and weigh well. If the book had contained only this final chapter the effort of writing it, and the probably even greater effort of publishing it in war-time, would have been amply justified.

Unfortunately the English translation is wholly devoid of the charm so characteristic of the French edition, but, as some compensation for this loss, Professor Morgulis has added to his translation a skeleton key to the literature in the form of a bibliography of about 300 entries. This should add materially to the usefulness of the book to readers unacquainted with the general field. In addition, a considerable amount of new matter has been added by the translator in his editorial capacity, but often to the detriment of the already fragile continuity of the text.

The reviewer felt that although, in the main, the translation is faithful to the original text, the translator should, in his capacity as an Editor, have taken more care to allow for the progress made in biochemistry as a whole during the five years which elapsed between the publication of the first French and the new American editions. It is somewhat distressing to read in 1949 that " the yellow enzyme takes care of fatty acid metabolism," and to find that the breakdown of adenosine triphosphate in glycolysis and elsewhere is still reported as yielding adenylic acid, rather than adenosine diphosphate. Nor are these the only examples of passages which would have been substantially the better for firm editorial revision.

Possibly because this new edition is in his native language the reviewer found Professor Florkin's occasional teleological tendencies

particularly glaring. It is, as the reviewer knows all too well, only too easy to fall into a mode of expression that, on analysis, is thoroughly teleological without necessarily holding a teleological point of view. Certainly there are passages in this book which could, and certainly should, have been more cautiously expressed unless, indeed, the author's attitude is in favour of teleology, which seems very doubtful. For instance, we are informed that " Evolution frequently utilises an already existing substance for a new function *by creating a new system of biochemical receptors for its action* " ; again, we read that " It is most probable that the accumulation of ammonia in the internal medium *was the reason* for the production of a much less soluble substance like uric acid " (reviewer's italics). Other passages could be cited. Unintentional lapses though these probably are, they must inevitably have consequences that will be regrettable for biochemistry among biologists in whom the spirit of one or another form of vitalism still lingers on ; and, what is perhaps even more to be regretted, among younger students who may read the book and find teleological habits of thought apparently approved of and accepted both by the author himself and by the combined person of his translator and editor.

Despite the comments and criticisms in the preceding paragraphs it must not be supposed that Professor Florkin's book is something to pass by. Taken as a whole, the book is a bold and a worthy contribution of great value to a grossly neglected field of scientific endeavour, and one deserving the widest possible biological public. In its new form it is attractively printed and well bound, although it contains too many typographical errors and not a few inaccuracies, not all of which have been carried over from the original French text. None the less, a careful reading—which will prove somewhat laborious—could do much to open the eyes and the mind of many a biologist and, to the biochemist, whose eyes hitherto have too often been averted from such a frankly biological approach to his subject, it will convey much that is stimulating and intriguing. If, as it may well do, this book persuades even a few biochemists to place more accent on the " bio- " and less on the " chemistry " than has hitherto been usual it will have done two great services to biochemistry as a whole ; first, by emphasising the interest and fundamental importance of a broad biological outlook for the biochemist himself and, secondly, by demonstrating to the biologist the applicability of biochemical concepts and techniques to fundamental problems in general biology.

STUDIES IN LUMINESCENCE. By G. F. J. GARLICK, B.Sc.,
Ph.D., F.Inst.P., University of Birmingham. Being a review of
Fluorescence and Phosphorescence, by PETER PRINGSHEIM.
[Pp. xvi + 794, with 219 figures.] (New York and London: Inter-
science Publishers, Inc., 1949. 120s. net.)

PROFESSOR Pringsheim is one of the few workers, still active in the
field of luminescence, who can provide from personal knowledge a
survey of development over the past fifty years or so. His first
book *Fluorescenz und Phosphorescenz* appeared in 1921, modest in
size and mainly devoted to fluorescence in the gaseous and liquid
phases. In his new volume of some eight hundred text pages he
has included a large section on the fluorescence of gases and vapours.
To many of us who are much younger workers in the subject these
aspects tend to appear as a branch of spectroscopy. From the
present book, however, we learn that there are many deficiencies in
the knowledge of fluorescence in gases that might be worthy of further
research. Professor Pringsheim notes the shift of interest in recent
years to luminescence in solids, particularly to luminescence in the
so-called " crystal phosphors." He attributes it to the growing
technical importance of these materials. Undoubtedly commercial
interest has prompted a large expansion of research on crystal
phosphors, but it must be remembered that there has been a parallel
growth of interest in the physics of solids, in which luminescence
is a phenomenon of considerable importance.

In its introduction the book calls attention to the techniques
used in the study of luminescence. Such techniques include the
various forms of Becquerel phosphoroscope. The modern use of the
cathode ray tube permits visual observation of the form of phos-
phorescence decay over a wide time range from microseconds to
hours, while supersonic cell fluorimeters enable fluorescence life
times shorter than 10^{-8} sec. to be measured. Measurements of
polarisation of fluorescence can provide valuable information about
the electronic structure of fluorescent molecules, but the author
might have stressed the danger of ambiguity of results when the
state of polarisation is not measured at all angles to the direction
of the radiation exciting fluorescence. We may also wish for more
adequate mention of such important sources of ultra-violet radiation
as the mercury and hydrogen high-pressure arc lamps, which are
almost indispensable in luminescence research.

It is surprising to find how few of the monatomic gases and
vapours have been thoroughly studied with respect to their fluor-
escence, notably sodium, zinc, cadmium, mercury and calcium. For
other gases experimental difficulties, such as the high temperatures

necessary for vaporisation, preclude accurate observations. Monatomic gases and vapours have relatively simple fluorescence characteristics and it is possible to make precise measurements of their line spectra, spectral line widths, life times of excited states, hyperfine structure, polarisation and quenching of fluorescence. The latter may be due to collisions between fluorescent atoms or between these atoms and those of foreign gases introduced into the system. Similar investigations are possible for diatomic gases, but fluorescence characteristics are complicated by the existence of vibrational states of the molecules. For such studies the halogens, and in particular iodine, were first selected by early workers. Few polar molecules are known to fluoresce in the vapour state, but among them silver chloride and thallous iodide have received some attention. Quenching of fluorescence in diatomic gases is more complicated than in monatomic systems, since it can arise from dissociation of the excited molecules. This probability of molecular dissociation is much greater in the case of polyatomic molecules and, in addition, fluorescence is much more likely to be quenched by " internal conversion " of the absorbed energy. Very few polyatomic molecules have been investigated in the vapour phase and only a few inorganic molecules, for example nitrogen peroxide and sulphur dioxide, are known to be fluorescent. It is much easier to study the fluorescence of polyatomic organic molecules in solution but, even so, by far the greater number investigated have been aromatic compounds.

Many more phenomena have to be included in the generic term *luminescence* when attention is turned to solids and condensed systems. Professor Pringsheim introduces the second part of his text with a general survey of these phenomena and of the important classes of luminescent solids. There may be several complex stages in the luminescence process between the initial absorption of energy by a solid and the final emission of luminescence. These include the process of energy transfer through the crystal, its storage for considerable periods of time before emission and its subsequent transport to the relatively few " centres " in the solid which are responsible for the final emission of radiation. Although much may be learned from the fluorescence of gases it is not usually possible to use this information to build up a comprehensive theory of luminescence in solids. For this purpose the wave mechanical models for crystalline solids, successfully applied to other phenomena, such as semi-conduction and the photographic process, have proved most useful. Among the interesting topics presented by the author in his survey we may note the relation of fluorescence to the process

of photosynthesis in living plants, the extensive studies of quenching of fluorescence in solution and the striking fluorescence effects observed in the formation of polymers of pseudo-isocyanine dye molecules. In the salting out of this dye from solution long threads appear containing thousands of molecules in card pack formation and each thread behaves as a single unit having a sharp resonance absorption-fluorescence band. A little more space might have been afforded to discussion of these effects and to the conflicting theories of their mechanism due to Scheibe and to Sheppard and his co-workers.

In considering the fluorescence of organic compounds Professor Pringsheim describes the early theories of chromatophoric and fluorescence groups in molecules and then shows how much more comprehensive and satisfying are the modern interpretations of colour and fluorescence due to wave mechanical treatment. It must be noted with regret that the contributions to the latter made by Coulson and his collaborators are not mentioned and the work of Sklar later than 1937 is omitted (see *Rev. Mod. Phys.*, **14**, 1942). A large amount of precise work on the luminescence of molecules dissolved in solids is due to the late G. N. Lewis. Long-lived phosphorescence is exhibited by fluorescein molecules in boric acid and changes of magnetic susceptibility accompany the excitation of luminescence. Kautsky has studied similar systems, particularly dye molecules adsorbed on silica gel. In his later publications (1947), not mentioned by the author, he describes the photochemical sensitisation of adsorbed molecules, which then function as sensitive detectors for very small traces of oxygen. The introduction of oxygen causes a brilliant emission of luminescence from the molecules.

Relatively few inorganic materials are luminescent in the pure state. These include rare earth salts and their ions in solution, which often exhibit line spectra when excited. However, the luminescence spectra are considerably modified when the ions are dispersed in solid media, such as glasses. Other pure materials which show luminescence include the uranyl salts, platinocyanides, siloxene and probably diamond, although the author attributes its luminescence to impurities. In reviewing the history of the studies of crystal phosphors, Professor Pringsheim observes that the extensive work of Lenard appears to have hampered progress because of the somewhat dogmatic theoretical views expressed in it. He stresses, with the wisdom born of long experience in this field, the necessity maintaining an impartial attitude towards the various past and current theories of phosphorescence and energy storage in crystal

phosphors. However, he states that phosphorescence of long duration is associated with materials having cubic or hexagonal crystal structures, although there are very many exceptions to this hypothesis, for example, manganese activated zinc silicates containing traces of arsenic and some manganese activated zinc-magnesium fluorides. Fluorescence and phosphorescence are often quenched by small amounts of deleterious impurities in phosphors. It is not true to say, however, that traces of calcium molybdate destroy the luminescence of calcium tungstate. The shift of the luminescence spectrum of natural scheelite ($CaWO_4$) to longer wavelengths (with no marked diminution in intensity) due to inclusions of calcium molybdate is used as an approximate method of analysis for tungstate ores.

No text concerned with the properties of crystal phosphors would be complete without a discussion of the electrical phenomena which accompany luminescence in zinc sulphide and some other phosphors. On excitation by ultra-violet light photoconductivity and large increases in dielectric constant and dielectric loss of the phosphor occur. These are associated with the movement of electrons in the phosphor crystals and their capture in metastable energy states, giving rise to highly polarisable systems. The author appears to be much more conversant with the earlier work on these phenomenon than with the more precise measurements and interpretations afforded by recent research. This may account for his confused presentation of the relations between luminescence and photoconductivity in silicate phosphors. He also assumes that such chemical compounds as zinc mesodisilicate and zinc metasilicate exist, although it has been known for many years that zinc ortho-silicate (Zn_2SiO_4) is the only real compound formed by zinc oxide and silica. Many natural minerals have interesting luminescence characteristics, often related to the discoloration of these crystals by energetic radiation or particles. These include uranium compounds, tungstates, diamonds, rubies, fluorites, kunzites and calcites. The author creates some confusion in discussing the studies of luminescence in diamonds, since he reverses the accepted classification of specimens into types I and II, as originally given by Robertson, Fox and Martin (1934). Diamonds of type I are opaque to radiation of less than 3000 A wavelength, non-photoconducting and exhibit a blue or blue-green fluorescence. Diamonds of type II are transparent to radiation of wavelength as short as 2250 A, are photoconducting and mostly non-luminescent.

Professor Pringsheim has provided an extensive bibliography of nearly 2000 references, together with author and subject indices.

Taken as a whole his book is certainly encyclopædic and in many detailed cases critical. The style is not very lucid and the second part on the luminescence of solids shows many signs of a partial appreciation of data. As the author points out, the text was virtually complete in 1946 and suffers from omission of much work published since then. As a general inference from this book it would seem that luminescence is becoming too extensive a subject to be dealt with in one volume or to be co-ordinated by one man. Professor Pringsheim is to be congratulated not only for his courage in attempting an appraisal of the whole field, but for the immense amount of material he has collected together in this book.

REVIEWS

MATHEMATICS

Theoretical Hydrodynamics. By L. M. MILNE-THOMSON. Second edition. [Pp. xxiv + 600, with 4 plates and numerous figures.] (London : Macmillan & Co., Ltd , 1949. 60s. net.)

ANY book on this subject has to satisfy two principal requirements · it must, to justify its existence, present the classical results in at least as clear a manner as hitherto, preserving at the same time the vitality of earlier writers, and it must include a certain amount of new material which is selected for its importance in the development of the subject It will bo generally accorded that this book, largely rewritten from the first edition, satisfies these require-ments adequately, although there must, of necessity, be slight divergence of opinion concerning certain minor items which have been omitted. It is evident that the author has an intimate knowledge of the subject matter and a wide experience in teaching it, and the book is distinguished throughout by its elegance and simplicity of treatment.

The structure of the book is not unlike earlier treatises, but the consistent application of vector methods makes the treatment much more concise than hitherto, and it is probably this feature more than any other which makes the book a valuable contribution to the subject. There are 20 chapters , Chaps. II and V are devoted entirely to Vector Theory and Complex Variable respectively, Chaps. XIX and XX to Viscosity and Compressible Flow respec-tively, and the remainder to the incompressible perfect fluid theory. Chaps. II and V, combined with later results in complex variable in the text, make the book quite self-contained, and for the student this will be a cardinal virtue.

In the incompressible perfect fluid chapters, in addition to the usual classical results, there are several notable features compared with earlier treatises. Use is made of the " circle " and " sphere " theorems (from which it is possible to write down the complex potential for the flow when a circular cylinder or a sphere is introduced into a given stream) ; the elegant work of Levi-Civita on the discontinuous flow past obstacles with curved boundaries is included ; the drag associated with the vortex wake is adequately discussed, and particular reference must be made to Chap. XVII, which gives a concise account of the Kirchoff-Kelvin theory of solids moving through liquids. This book of course is already a large one, but it is a little surprising to find that the classical tidal theory receives on the whole rather scant attention. There is no reference either to the important analogy pointed out by Riabouchinsky between compressible flow and shallow water wave theory. These, however, are minor blemishes in a comprehensive text.

The chapter devoted to viscosity contains all the standard results, but is notable for its inclusion of the important investigations of Filon and others

into the forces on a cylinder in a viscous fluid. The boundary layer theory is, on the whole, adequately introduced ; the flat plate problem is solved by Lamb's method and the opportunity of utilising the Weyl-Meksyn technique in such problems has not been taken.

The chapter devoted to compressible flow is a good summary of the important aspects of this rapidly widening field. There is a reference only to the linearised theory (which topic is treated in the author's *Theoretical Aerodynamics*), but the hodograph method, with the well-known results due to Chaplygin, and the particular cases of exact solution investigated by Ringleb and Temple are given. Characteristics and shock waves are discussed with considerable clarity and Meyer's important contribution in characteristic theory is included.

This book will certainly meet the requirements of honours mathematics students in the universities and, even though some of the contents of the book, for example Chap. II, will have been encountered by such students in other courses, it is unlikely that the material could be more ably presented than here.

T. V. D.

Giant Brains or Machines that Think. By E. C. BERKELEY. [Pp. xvi + 270, with 77 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 32*s*. net.)

THIS book presents what is probably the first attempt to describe in popular terms the developments in computing machines which have taken place in the last decade. After a brief introduction, which reads rather like a defence of his choice of title, the author introduces the ideas involved in modern computing machines by describing the construction of a simple machine which is capable of carrying out sequences of elementary arithmetic and logical operations. This machine has two paper tape inputs, on the first of which it receives coded instructions and, on the second, the numbers on which the operations are to be performed. This section is one of the most satisfactory in the book, as it comes nearest to satisfying the demands of the wide range of readers for which it was intended.

The next few chapters are devoted to descriptions of a number of specific large-scale computing machines which were in operation before the end of 1947. They include the standard I.B.M. punched card machines, the second M.I.T. Differential Analyser, the Harvard Automatic Sequence Controlled Calculator, the ENIAC and the Bell Telephone General Purpose Calculator. These descriptions frequently suffer from the author's attempts to cater for a wide variety of readers. This is particularly noticeable in the chapter on the differential analyser, in which, for instance, very elementary definitions of differentiation and integration are included. The descriptions of the standard I.B.M. punched card machines, however, are exceptionally clear, and should serve as an excellent introduction to them for any reader. The last chapter on computing machines gives a brief summary of some of the new machines which were under construction when the book went to press.

Mr. Berkeley concludes with two chapters of a more speculative nature the first on the future of " machines which think " and the second on the sociological implications of these developments.

This book is clearly not for the specialist in this field, but it can be strongly

recommended to anyone who wishes to gain a clear idea of the general scope and the objectives of recent developments in computing machines.

J. H. W.

The Scientist's Ready Reckoner. Logarithmic Tables for all those engaged in physical and biological sciences. By W. ROMAN, Ph.D., A.F.Inst.Pet. [Pp. viii + 142.] (The Hague : Dr. W. Junk, Publishers, 1950 ; London Agents : Wm. Dawson & Sons, Ltd. 15s. net.)

THE first half of this book comprises tables of atomic weights, multiples of the atomic and molecular weights of some common atoms and groups, molecular weights of molecules and radicals with multiples and submultiples in common use, gravimetric factors and titrimetric equivalents, together with their logarithms in each case. The second half includes tables of the densities at 15° C. of aqueous solutions of ammonia, ethyl and isopropyl alcohols, proof spirit, hydrogen peroxide, and acids and alkalis on various scales, tables for the conversion of temperatures from the absolute or centigrade scales to Fahrenheit, four-figure logarithms and antilogarithms, and five-figure logarithms.

Although the book will not find very wide usage in university and college laboratories, it will undoubtedly be extremely useful in some industrial laboratories where ready access to these data is a daily necessity. The type used is small but very clear, and a marking device permits the table required to be found very rapidly.

J. W. S.

ASTRONOMY AND METEOROLOGY

The Face of the Moon. By RALPH B. BALDWIN. [Pp. xiv + 239, with frontispiece, 17 plates and 26 figures.] (Chicago : University of Chicago Press ; London : Cambridge University Press, 1949. 40s. net.)

THE origin of the lunar craters has been for nearly a hundred years a bone of contention among astronomers. Controversy has centred around variations of two major themes, the volcanic and the meteoric hypotheses, and to the present day opinion is as strongly divided as ever.

During the recent war, Dr. Baldwin left his astronomical studies for the development of explosives. He brings to the lunar battlefield an intimate knowledge of both astronomy and explosion ballistics, and has come to favour the meteoric theory. In developing the arguments which lead him to this decision he begins, conventionally, by contrasting the appearance of a lunar crater and a terrestrial volcano, but such comparisons cannot yield conclusive evidence because of the very different physical conditions on the two bodies. He next examines in detail various statistical relationships between lunar crater features, which clearly demonstrate a common origin for nearly all of the craters. He then breaks new ground by comparing the height/diameter relationship for terrestrial bomb craters, the few known terrestrial meteor craters, and the lunar craters, and all are found to lie on a smooth curve. This graph is the core of his thesis, and, while it may be taken as a reasonable indication of an explosive origin, it does not warrant the conclusion drawn, that the cause of the explosion is external and therefore, *ipso facto*, meteoric. Finally, evidence for fossil terrestrial meteor craters is critically examined.

and the rate of occurrence of such craters throughout geological times so deduced is found to be consistent with the observed density of lunar craters. A chapter on the possibility of a lunar atmosphere is included, while the bibliography of some 150 references testifies to the author's thorough examination of the problem.

In short, Dr. Baldwin presents a case for the meteoric theory which demands attention, but it is far from being conclusive or unassailable. It is to be hoped that a counter-offensive of equal merit from the camps of vulcanism will not long be delayed.

M. W. O.

The Atmospheres of the Earth and Planets. Edited by GERARD P. KUIPER. [Pp. viii + 366, with frontispiece, 16 plates and 91 figures.] (U.S.A. : University of Chicago Press ; Great Britain and Ireland : Cambridge University Press, 1949. 60s. net.)

THIS volume is a compilation of papers presented by some seventeen authors at a symposium sponsored by the University of Chicago in connection with the fiftieth anniversary of the Yerkes Observatory. About three-quarters of it is devoted to the discussion of problems connected with the earth's atmosphere, mainly in its upper levels. Of particular interest is the account, in Chap. IV, of the new knowledge obtained by means of high-altitude rockets, and of the methods by which the very considerable experimental difficulties encountered in this work have been overcome. Less sensational, perhaps, but of no less scientific importance, is the account of conditions in the highest levels, i.e. above 300 km. There is also a most stimulating account of the geological evidence on the evolution of the earth's atmosphere ; the author, the late Dr. R. T. Chamberlin, makes out a good case for his claim that the application of geological knowledge to the problems presented by the history of the atmosphere provides a fruitful field for further investigation. The chapter on the spectra of the night sky and aurora is an authoritative account, valuable not only as a lucid exposé of a difficult subject, but also as giving clear indications of the more important gaps in our knowledge and how they might be filled. Several other topics are dealt with, all very adequately, and the omission of others is justified by the explicit limitation to such aspects of the earth's atmosphere as lend themselves to a comparison with planetary atmospheres in general. The ionosphere and related phenomena, for example, receive only casual mention.

The principal contribution to the astronomical section of the book is by Dr. Kuiper, the editor ; it is a fascinating summary of the latest results and conclusions regarding the atmospheres of the planets. Such a survey is of particular value at the present time, in view of the rapid rate of recent progress in this field. It is supplemented by chapters dealing with infra-red planetary spectra (Adel) and recent work at Mount Wilson (Dunham). The experimental spectroscopist will find much to interest him in Dr. Herzberg's account (Chap. XIII) of absorption spectra of gases obtained with very long paths ; in fact, this may be said to open up a new field, among the first-fruits of which may be mentioned the quadrupole absorption lines of H_2 in the photographic infra-red, and the absorption spectrum of O_4.

In a compilation of this kind it is almost impossible to avoid some over-lapping and occasional discrepancies, but the present work, thanks no doubt to careful editing, is commendably free from such defects. The only instance

of the latter type which has been detected is the conflict between the statements on p. 14 (no CO_2 on Mars) and p. 335 (CO_2 found on Mars), and this is presumably attributable to inexact synchronisation of revision of the chapters. The production of the text and plates is excellent, and the volume is in every way a worthy commemoration of the jubilee of one of the most famous of observatories.

W. E. C.

Cosmical Electrodynamics. By H. ALFVÉN. The International Series of Monographs on Physics. [Pp. viii + 237, with 78 figures.] (Oxford: at the Clarendon Press, 1950. 25s. net.)

THIS is a very important book. The researches of the author in this field, in which he is the world's leading specialist, extending over the last thirteen years are well known, and it is most welcome that they are now collected in one volume. It is a field of almost inexhaustible interest, which has hardly been tapped. The author rightly emphasises that the purpose of his book is more to pose problems than to solve them, and he is deservedly critical of theories " which are hardly more than a complicated way of expressing our ignorance."

Indeed, it is extremely easy to go wildly wrong in this field when relying on instinct. Whose instinct would tell him, for instance, that the conductivity of interstellar space, with about one ion per cm.^{3} is only about 10,000 times worse than that of copper ; hence a galactic magnetic field, if it exists, would be so effectively " frozen in " that its relaxation time would be of the order of 10^{34} years ? Or who would think that the weak diamagnetism of an ionised gas, almost impossible to measure in the laboratory, might be strong enough to eject huge clouds from the sun ? It is one of Alfvén's chief merits to have directed attention to just those features of electromagnetism which are usually not considered worth mentioning. Consequently the reader, who first looks up the table of contents and finds that only 21 pages are given to electron dynamics and 34 pages to the vast subject of electric discharges, will have a pleasant surprise when he sees that these chapters contain almost exclusively material which is missing from most large textbooks. Unipolar induction, the bogey of engineers brought up in ignorance of relativity, is shown to be one of the most important electromagnetic agents on the cosmic scale. But the potential reader who might not feel very strong in relativity may be assured ; Prof. Alfvén uses only the simplest mathematics.

Perhaps the most important of Alfvén's contributions to the subject is the theoretical discovery of magneto-hydrodynamic waves, whose existence has been only quite recently demonstrated in the laboratory, by S. Lundquist. Probably the most brilliant achievement of this theory is the explanation of sunspots, by Alfvén and Walén, as due to whirl rings, originating in the interior of the sun, at the boundary of the stable region, which rise to the surface, carrying strong magnetic fields with them. Though at present there may be some doubt about the origin of these rings, in view of the recent low estimates of the sun's dipole field, one cannot help feeling that a theory which explains so many details must have a large element of truth in it.

The theory of magnetic storms and auroræ may be, however, a warning. It appears that there is little basis now for the Störmer-Vegard theory, which was apparently so successful, and it may have to be replaced by a

" discharge theory," on almost opposite foundations. The various theories of cosmic radiation, put forward by the author and others, rest probably on an even more uncertain basis, but they are equally fascinating.

The book may be recommended not only to professional astrophysicists, in whose case a recommendation is superfluous, but also to every reader with a philosophical interest in the universe, and a solid, but not necessarily specialist, knowledge of physics. Though the author makes no attempt to glamorise the subject, his work gives often enough a thrill familiar to the readers of Eddington, Jeans and Hoyle.

D. GABOR.

Interplanetary Flight. By A. C. CLARKE, B.Sc. [Pp. viii + 164, with 16 plates and 15 figures.] (London : Temple Press, Ltd., 1950. 8s. 6d. net.)

IF the writing of books could bring us nearer the planets, our goal should not be far off. Since the invention of the V2 rocket in the late war, there has been a spate of books on interplanetary travel, the authors of which suffer from the disadvantage of having to describe what may be, rather than what has been, accomplished in their science. To the reader with a Wellsian attitude of mind to the applications of science such a book as the present one can be intensely interesting. To one with experience of wartime rocketry, it is interesting to note that the rocket is in process of being dethroned from its unjustified position as " space-ship number one " and that its practical limitations are now realised in the British Interplanetary Society !

E. G. R.

Between Earth and Sky. By AUGUSTE PICCARD. Translated by CLAUDE APCHER. [Pp. 157, with 60 plates and 13 diagrams.] (London : The Falcon Press, 1950. 15s. net.)

PROF. PICCARD also takes us on an interplanetary rocket-propelled flight towards the end of his book, though from some things he says about the rocket one judges that his acquaintance with that " misguided projectile " is based on Newton's laws and not on practical experience. His own sensational stratosphere balloon flights of 1931–34 occupy but a small section, the main theme being the meteorology of the upper atmosphere. Those who require a popular and entertaining account of this subject are well served herein by Prof. Piccard, ably assisted—except for perpetrating a few unaccustomed technical terms—by his translator.

E. G. R.

PHYSICS

The Meaning of Relativity. By ALBERT EINSTEIN. Fourth edition. [Pp. vi + 145.] (London : Methuen & Co., Ltd., 1950. 7s. 6d. net.)

THE first 76 pages of this book reproduce the original edition which was written in 1921, and are of great historical interest, for they give the point of view of the founder of relativity theory at the time when he put it forward. The standpoint is necessarily that of a man steeped in the ideas of nineteenth century physics, but who is breaking through them towards a new conception of mechanics. What the reader will miss in these chapters is the effect of the

break-through which, during the past thirty years, has itself reacted on relativity theory and on the reasons for accepting it.

The first appendix originally appeared in the third edition of 1946 and is an argument for asserting that the cosmical constant has the value zero. It is well known that the value of this constant can be determined from observations of the average motions and distribution in space of the extra-galactic nebulæ, but that, until the observations from the 200-inch telescope become available, this value is uncertain. Einstein gives little weight to such an observational determination and suggests that the cosmical constant ought to have the value zero on the basis of the *a priori* principle of " logical economy."

The second appendix—of length 15 pages—is new and contains an account of the unified field theory of gravitation and electromagnetism which was announced in the public press at Christmas 1949. It is a unified theory of " classical " type, *i.e.* it follows in the tradition of the first theory of this kind enunciated in 1918 by Hermann Weyl and does not incorporate the notion of discontinuity which has since become familiar to us in the quantum theory. A non-Riemannian geometry is employed in which the symmetrical metrical tensor of Riemannian geometry is replaced by a tensor which has both a symmetrical and an asymmetrical part. No physical interpretation of this tensor is given. Hamiltonian differentiation of an invariant formed out of the generalised " curvature " tensor yields field equations in the usual way. A short final paragraph of a dozen lines indicates which of these field equations might refer to the electromagnetic field. During the past thirty years it has been shown that unified field theories of this kind come to grief as soon as particular solutions of the proposed field equations are worked out. It may well be thought a matter for regret that this test was not carried out on the new theory before its publication was announced.

G. C. McVITTIE.

Practical Applications of Spectrum Analysis. By H. DINGLE, D.Sc. [Pp. x + 245, with 19 plates and 37 figures.] (London : Chapman & Hall, Ltd., 1950. 40s. net.)

WE welcome indeed this new contribution to a field sadly lacking in such books. As is only to be expected from Prof. Dingle, this treatise is very much a personal record, and all the more valuable for that, since Dingle was for many years the right-hand man of A. Fowler and carries with him the long and great spectroscopic tradition of the Imperial College at London.

The book contains 130 pages of text, the remainder being tables for line identifications. There are eight chapters containing (a) sources, (b) prism spectrographs, (c) grating spectrographs, (d) determination of wavelengths, (e) qualitative spectrum analysis, (f) quantitative analysis.

The author has clearly borne in mind the needs of the *majority* of those who use or could use spectrum analysis, having kept down to a minimum the theoretical aspects and restricted his description of sources to the simpler types, which most laboratories either have or can readily acquire. If any appreciable criticism is at all to be made, it is that this section on sources might have been expanded with advantage.

The sections on spectrograph designs are attractive. Chap. V includes (together with Appendices III and IV) that most valuable quick method for

the reduction of prism spectrograph measurements taught to all students who pass through the Spectroscopic Department of Imperial College. However, the really invaluable section of the book begins in Chap. VI in which the author, from a deep fund of experience, reveals the many pitfalls awaiting the unwary, especially with regard to preparation of sources. Chap. VII contains *raies ultimes*, with pointed comments on interpretation, for some 60 elements. It is questionable whether the introduction here of a simplified notation for the description of multiplets is worth while; it only means an additional notation to be remembered.

This is essentially a handbook for the practising spectroscopist and will undoubtedly find much favour in metallurgical and analytical chemical laboratories, for it describes the " know how," rare enough nowadays in most spectroscopic books. One gets the impression that the author is not yet happy about the status of accurate quantitative spectrum analysis as such and he does not devote much space to this aspect.

The book is beautifully illustrated by plates, which constitute an important part. A regrettable feature is the very high price, to which no doubt the abundance of plates has contributed.

The style of writing is most attractive and, as one would expect from Dingle, there are some characteristic shafts at " definitions " and nomenclatures.

S. T.

Sound. By F. G. Mee, M.A., B.Sc. [Pp. x + 171, with 5 plates and 95 figures.] (London : William Heinemann, Ltd., 1950. 8s. 6d. net.)

Those who teach physics in the upper forms of secondary schools and intermediate Science students will welcome this textbook. The author has taken care in the choice of his material both to interest the reader and to give a summary of the results of recent research. A feature is the number of illustrations both of musical instruments and of the waveforms of the sounds they emit. Though the emphasis of the book is on experiment, the author is not afraid to introduce a little theory and therein to employ the calculus.

He suggests that some of the neglect of the subject in the school physics syllabus is due to the difficulty of setting numerical examples other than a few hackneyed types. Not the least important parts of the book are the grouped examples, some from recognised examinations and others specially devised, which show what can be done by the venturesome examiner.

E. G. R.

Acoustic Measurements. By Leo L. Beranek, S.D., D.Sc.(Hon). [Pp. viii + 914, with 519 figures.] (London : Chapman & Hall, Ltd., 1949. 56s. net.)

Dr. Beranek has compiled a most detailed volume on the methods of making acoustic measurements. He describes the well-established techniques and the reasons for their adoption and also gives details of more recent methods which are not yet fully established in the art. The bibliography is extremely comprehensive and will be of great use to research workers and others who wish to consider the subject in much greater detail ; but enough information is given to satisfy acousticians who need only apply known techniques and

wish to do it intelligently without delving into the literature. The writing is concise and lucid and the book is a valuable work of reference.

The book commences with the fundamental theory underlying acoustic measurements and then goes on to microphones, measurements of frequency and acoustic impedance. In the next chapters complex waves are discussed and methods and instruments for the measurement and analysis of them are described. Then follow chapters on the testing of communication systems and their component parts such as amplifiers, microphones and loudspeakers. The final chapters are concerned with articulation testing, measurements of acoustical materials and the acoustics of auditoria and studios.

The only criticism which might be made is that, although the author has discussed in several places the subjective aspects, he does not emphasise that acoustic measurements are valueless if the results do not agree with the subjective analysis of listeners.

T. S.

Introduction to Statistical Mechanics. By R. W. GURNEY. International Series in Pure and Applied Physics. [Pp. viii + 268, with 59 figures.] (New York, Toronto, London : McGraw-Hill Book Co., Inc., 1949. 30s. net.)

IN the preface of this book the author makes the comment that a widespread belief exists among students of physics and chemistry that statistical mechanics is necessarily abstruse and difficult. This book, he remarks, has been written to show that such a point of view is mistaken. These comments underline the general trend of the book. The subject matter is roughly the same as in other elementary treatises ; but it is examined in greater detail by simple qualitative arguments without much of the usual mathematical apparatus.

The first part of the book (Chaps. I-VII) deals with the theory of what might be termed the " Boltzmann assembly." The macroscopic properties of real systems are derived from a hypothetical assembly of slightly interacting systems, each system having a series of possible discrete energy levels. The author thus treats the quantum mechanical formulation as basic and the classical as derivative. This point of view has much to be said for it, although it is naturally the reverse of the historical development of the subject. In the first chapter it is shown in a very clear elementary way, with interesting numerical applications, how the usual distribution law follows naturally from the basic assumption of equal probability of discrete quantum states.

The subsequent chapters introduce the idea of temperature and examine simple systems, for example, gases and saturated vapours. Chap. VII gives a very readable account of liquid and solid solutions, including some hitherto unpublished work by the author on the alloys of iron.

In Chap. VIII the more powerful method of the Gibbs ensemble is introduced. Later chapters give accounts of the theory of gases, specific heats of solids, chemical dissociation, electrons in metals and other topics.

Like the author's previous books, the present work is very carefully written. But to a reader able to follow a more abstract approach, much of the argument will seem unnecessarily laboured and tedious. Also in a book of this kind, some account of the historical background would be very desirable, both for its own sake and as a guide for further reading.

BOOTH.

The Physics of Rubber Elasticity. By L. R. G. TRELOAR. Mono-graphs on the Physics and Chemistry of Materials. [Pp. viii + 256, with frontispiece and 114 figures.] (Oxford : at the Clarendon Press, 1949. 21s. net.)

A MAJOR development in the last two decades in the field of high polymer materials has been the expression of their mechanical properties in structural, energetic and molecular terms. This has successfully invoked such a variety of analytical and experimental techniques (so distinct from the classical elastic methods appropriate to the small strains of ordinary engineering materials) and is vital to such practical industries as rubbers, fibres and textiles—quite apart from biology—that fittingly this fourth volume of these Oxford mono graphs covers much of this ground.

Dr. Treloar's gifts of critical thinking and clear statement, together with his wide experience of research in the rubber (and now rayon) field, have combined to produce an able and knowledgeable work, up-to-date, excellently illustrated, fully documented in its selected range and of wide and timely appeal. Following introductory chapters on general physical properties of elastomers and the development of the general thermodynamic formulae the simplified statistical theory of long chains and their networks is outlined and the broad extent to which experiment confirms them is detailed. Refine ments necessary in particular applications are then discussed, and the value of optical, X-ray and thermal methods shown in mechanical and photo elastic property analysis and the nature and bearing of crystallisation. The final chapters deal with plasticity, dynamic properties and large elastic deformations, shear and compression as well as elongation. Assumptions and approximations are clearly stated and practical difficulties in attaining necessary equilibrium conditions stressed.

One major criticism : doubtless of set purpose the author has concen trated on the statistical and kinetic approach in which chemical nature is subsidiary. One hopes that in a future edition he will put us further in his debt by including more polar systems in which elastic deformations connote order-to-order as well as disorder-to-order processes, with energy not entropy the major factor. This touches intimately the muscle problem and biological systems. If " rubber " is to retain the general sense in which it is here used much in recent muscle symposia and in fibrous protein studies merit incorporation.

I. MacARTHUR.

Theory of Dielectrics. By H. FRÖHLICH. Monographs on the Physics and Chemistry of Materials. [Pp. viii + 188, with 47 figures. (London : Oxford University Press, 1949. 18s. net.)

THE theory of dielectrics is one of those topics that stand on the borderline between classical and quantum mechanics, bridging the gap between micro scopic (i.e. atomic and molecular) and macroscopic (i.e. large-scale, or statis tical) phenomena. More recently, as a result of improved technique in the microwave region, it has acquired considerable importance in the experimental study of high polymers, rubber, internal rotation in solids and degree of association in liquids. So much has happened since van Vleck wrote his *Electric and Magnetic Susceptibilities* or Debye his *Polar Molecules* that evidently the whole subject is in need of a rewriting that would ti

on the one hand recent analysis, such as that of the internal field due to Onsager and Kirkwood, with its bearing on the determination of static molecular dipole moments, and on the other hand the enormous development of Debye's early analysis of dielectric loss.

Prof. Fröhlich has attempted to do this rewriting. In a book of less than 200 pages some condensation is inevitable, and he has quite wisely decided to accept without discussion the main ideas of quantum theory, such as stationary states and spin, and also some elementary statistical mechanics. The lay-out of the book is quite simple. After an initial short chapter devoted to macroscopic phenomena, the static theory of polar material is developed up to the stage where some quite general new theorems are proved, which in principle (though not yet in practice) permit a complete description of the dielectric constant of simple media. This is followed by a chapter on periodic phenomena, which are seen to be so much more complicated than the static ones that relatively little fundamental progress has been made. It is, however, important to be sure under what conditions Debye's famous equations of dielectric loss are valid ; failure to realise these conditions has led to some bad mistakes in the literature. The third, and final, part of the book is devoted to applications of the theory. It is very interesting to see so many of these together, and their elucidation is impressive. But it is nevertheless with a sense of sudden discontinuity that we pass from the rather formal analysis of the first two main sections, where all detailed applications have been so carefully eschewed that it reads like a mathematical text-book, to the experimental third section. The reviewer doubts whether many of the experimentalist readers for whom the book is designed, will have stayed the course up to this stage. It may be true that " the mathematical technique required only occasionally exceeds acquaintance with the calculus," but the extremely careful, accurate and guarded development of the theory will certainly appear too severe for the biologists mentioned in the preface, who, if they were prepared to go steadily through it, would certainly survive knowing much more of their subject and possessing a healthy respect for it. The fact that a second printing has been required so soon after the first indicates that this timely book meets a genuine need.

<div align="right">C. A. COULSON.</div>

Atomic Energy. Edited by J. L. CRAMMER and R. E. PEIERLS, C.B.E., F.R.S. [Pp. 200, with 16 plates and 24 figures.] (Harmondsworth : Penguin Books, Ltd., 1950. 1s. 6d. net.)

THIS book has grown from the decision, when the re-issue of *Science News* 2 became possible, not only to revise the existing material, but to enlarge the scope of the book by the introduction of new chapters on the growing constructive applications of nuclear energy and the techniques of nuclear physics. The result is a popular but quite substantial textbook of nuclear physics by foremost masters of the subject. While the book as a whole has gained in stature, one may regret the detailed pre-eminence which still falls to the bomb, for there is little reason to suppose that the undoubted fascination of the machinery of an atomic explosion is conducive to a balanced understanding of the impact of nuclear power release on human affairs. By any standard, however, *Atomic Energy* is an outstanding achievement.

<div align="right">J. G. WILSON.</div>

Photons and Electrons. By K. H. Spring, M.Sc. Methuen's Monographs on Physical Subjects. [Pp. viii + 108, with 38 figures.] (London : Methuen & Co., Ltd., 1950. 7s. 6d. net.)

The development of machines for the production of high energy electrons has renewed interest in the interaction of electromagnetic radiation with matter. The classical work dealing with such phenomena is Heitler's *Quantum Theory of Radiation*, in which the point of view is mainly theoretical, although valuable comparisons with experimental results are also made. The present little work, which is the latest addition to the series of Methuen's Monographs on Physical Subjects, aims at presenting the results of the theoretical calculations and their comparison with experiment in a readily accessible form, without going into detail in the description either of the theoretical bases of the calculations or the experimental technique employed in the measurements. The author has succeeded admirably in his aim and a stimulating monograph has resulted, which should be very useful indeed for the research worker, either theoretical or experimental, in this field and also for those with a less specialised interest, who are anxious to get some idea of the present position in radiation physics without going too far into technical details.

The choice of subject matter shows careful and intelligent discrimination and the physical ideas behind the theory are well presented. After a chapter dealing with the fundamentals of radiation theory, successive chapters deal with the photo-electric effect, the Compton Effect, radiation accompanying the passage of electrons through matter, the production and annihilation of positrons and cosmic-ray phenomena.

The book does not discuss problems such as the scattering of electrons by electrons and nuclei, nor are the implications of the recent refinements to radiation theory introduced by Tomonaga, Schwinger and Feynman, etc., discussed, but nevertheless it forms a worthy addition to the many other excellent monographs already published in this series.

E. H. S. B.

Counting Tubes : Theory and Applications. By S. C. Curran, Ph.D., F.R.S.E., and J. D. Craggs, M.Sc., Ph.D. [Pp. xii + 238, with 119 figures.] (London : Butterworth's Scientific Publications, 1949. 35s. net.)

This monograph is a welcome addition to the growing number of books on the subject. It consists of twelve chapters dealing with various aspects and designs of electrical counting devices, and it contains many useful facts and experimental hints which could only have been collected by workers actually engaged in this field over a considerable period. As the authors indicate in the preface, they have wisely concentrated on drawing attention to counter methods " in the hope that they will age less quickly than the interpretation of the results." Besides a description of ionisation chambers, proportional counters and Geiger counters, attention is devoted to newer developments such as photomultipliers, scintillation counters, crystal counters and spark counters. The subject matter is well arranged and the general presentation could hardly be improved. The total number of references varies from 20 to 60 per chapter and the number of workers listed is about 350. Disapproval may be expressed on a few secondary matters. The present treatment of references seems very capricious and it is sometimes

irritating. For example, on p. 78 one.worker is named three times in sixteen consecutive words, while on p. 206 another worker is named seven times, all with reference to the same piece of work. On the other hand, other workers responsible for important developments are often referred to only as a number, except in the list of references. This is misleading, because the inference might well be that the importance to be attached to a piece of work was proportional to the emphasis placed on the name and, indeed, the authors frequently act as judges in this connection, describing work as important, elegant or admirable. Definite objection must be raised against the use of ambiguous adjectives like " fine " on p. 160, while " state " is to be preferred to " status " on p. 187. The use of " homogeneous " on p. 153 is also misleading, since a search is being made for inhomogeneity of charge, whereas the word presumably refers to energy, although this is not obvious since the β-rays are from Ra E. It seems hardly necessary to waste space on the theory of the Compton effect on p. 161 ; on the other hand, more attention might be devoted to presenting some of the diagrams of apparatus in bolder line.

F. C. CHAMPION.

Microwaves and Radar Electronics. By ERNEST C. POLLARD and JULIAN M. STURTEVANT. [Pp. viii + 426, with 193 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1948. 30s. net.)

THIS book provides an introduction to many of the radio techniques which, originally developed for radar, are now finding application in many other fields, notably in physics and chemistry. Based primarily on the authors' experience of radar work at the Radiation Laboratory, M.I.T., and of American post-war developments, the book may well be described as a pocket edition of the M.I.T. 27-volume series of textbooks.

A very wide range of subjects is covered. The first half of the book deals with microwave techniques and devices, commencing with a guide to the theoretical treatment of the associated field problems and proceeding to utilise this in the practical discussion of many microwave components under the chapter headings : Coaxial Lines ; Waveguides and Cavities ; Production of Microwaves ; Microwave Technique. Then follow four chapters on techniques for the production, use and measurement of short pulses. A chapter on servomechanisms and computers leads to the final four chapters devoted to descriptions of systems and applications of the techniques in the fields of radar, communications and finally in physical research. Three short appendices (Fourier Integral, Stokes' Theorem, Units) and adequate indexes complete the book.

The condensation of so much material into 400 pages has been effected, quite admirably, by providing the introduction to the different branches of the art through discussion of well-selected representative topics. Salient features are well treated and unnecessary detail has been eschewed. Practical considerations are emphasised, and practical numerical data are well in evidence.

This is no textbook providing a complete logical treatment, but is a guide for those who may have to use radar techniques and who need an introductory survey sufficient to give an intelligent understanding of the available techniques and an indication of new fields of application.

An error on p. 91 was noted, where,the figure 2·405 should be replaced by 1·841 in equation (4.1).

The book is well produced and the numerous illustrations combine with its readability to make it an attractive introduction to the subject for the engineering or physics student.

N. ELSON.

Aerials for Centimetre Wavelengths. By D. W. FRY and F. K. GOWARD. Modern Radio Technique Series. [Pp. x + 172, with 65 figures.] (Cambridge : at the University Press, 1950. 18s. net.)

WAR-TIME research in radar led to many interesting developments, not least being the new approach to aerial design made necessary by the introduction of centimetric wavelengths. The authors of this book have performed a useful service in collecting together a great deal of information (mainly British) on this work, in which they themselves played a considerable part at T.R.E.

The first chapter discusses the requirements which must be met by radar aerial systems. Polar diagram theory, one of the most interesting aspects of modern aerial design, is treated in the next chapter. The physical significance of the mathematics is clearly brought out, and an illuminating comparison of the Fourier and " optical " methods of beam shaping is given. A brief description of various types of centimetric aerial follows, and the usual convenient distinction between primary and secondary radiators is explained. Subsequent chapters discuss in detail the use of single and double curvature mirrors and lenses as secondary radiators, together with suitable " line " and " point " source primary radiators. The basic principles explained in the earlier chapters are applied to many different types of aerial, and methods of producing narrow " pencil " beams and specially shaped (*e.g.* " cosec ") beams are discussed.

In an appendix, several omni-directional, non-scanning aerials suitable for use at microwave frequencies are described, and the optical terminology employed in the main text in dealing with the aberrations of lens and mirror systems is explained.

The illustrations include a considerable number of radiation patterns actually obtained in practice on aerials designed by the various techniques described. In this connection, however, it is unfortunate that the cosec patterns shown give little information about low-angle lobes. Such lobes are a source of trouble in some applications.

It is no doubt an oversight that the word " gain " does not appear in the index.

The main concern of the book is with the theoretical and practical principles of design rather than with the provision of data, and in this respect the authors are to be congratulated on having produced a readable and comprehensive account.

A. L. CULLEN.

Transformation Calculus and Electrical Transients. By STANFORD GOLDMAN, Ph.D. [Pp. xiv + 439, with 185 figures.] (New York : Prentice-Hall, Inc. ; London : Constable & Co., Ltd., 1949. 30s. net.)

THIS is an excellent textbook. Intended for graduate students in electrical engineering or applied mathematics, its main purpose is to show how the

transient currents occurring in disturbed electric circuits and transmission lines may be calculated by first applying the Laplace Transformation to the appropriate ordinary or partial differential equations, and then applying the inverse transformation. The topics covered include the Expansion Theorem, the Inversion Theorem and the associated use of residue theory, the Superposition and Convolution Integrals, the step function, impulse functions of multiple order, asymptotic solutions and Nyquist's stability criterion. The relations of Laplace transforms to Fourier transforms and to Heaviside's operational methods are clearly exhibited.

In addition, there are chapters on mathematical topics needed as a background. Thus there are chapters on Determinants, on Functions of a Complex Variable, on Loci of Complex Functions, and on Gamma, Error and Bessel functions. Some of the results given are proved, others quoted, footnote references being supplied. Where a proof lacks rigour, this fact is nearly always made clear and discussed. Further background material is supplied by an excellent chapter on electric circuits, in which all the necessary basic concepts and mathematical formulations are carefully recalled, some welcome sections on phase-attenuation relations and an appendix on Transmission Line steady-state theory. If the book had consisted merely of these cited items, it would have constituted a very valuable reference book for any electrical engineering student.

The book is only an introduction to its subject (being, for example, less advanced than the well-known works of Carslaw and Jaeger, or McLachlan), but as such it could hardly be bettered. On reading it, one realises that the writer is, here, essentially a *teacher*. The general exposition is very lucid and thorough, every step being carefully explained. Further, the author spares no pains in explaining or commenting upon points of importance or interest to students, which a less conscientious writer might easily have ignored.

Numerous illustrative examples, mostly electrical and of intrinsic interest, complete a book which it is a pleasure to read.

<div align="right">A. Talbot.</div>

CHEMISTRY

Boron Trifluoride and its Derivatives. By H. S. Booth and D. R. Martin. [Pp. x + 315, with 40 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 40s. net.)

Boron trifluoride is indeed a versatile compound but its activities are adequately covered by this monograph, which surveys the literature up to January 1948, with one or two subsequent papers. This however is only to be expected when, as is stated in the preface, *Chemical Abstracts* has been scanned page by page. The advantage of this coverage is somewhat modified because, as a result, the book is non-critical and too much like a catalogue. Thus there is no discussion as to what extent the complexes reported to be formed by boron trifluoride and the inert gases may be regarded as " compounds." Again, many low temperature-composition diagrams for binary systems are given, but there is no discussion of the extent to which absence of compound formation may be inferred from thermal analysis ; the main features of the experimental technique used for the construction of such low temperature-composition diagrams might well have been included.

Some minor defects noted are : use of the sign · for multiplication (p. 19) although the sign × is also employed (p. 54), " decreases " is given for " rises " (p. 146, line 17), tetra-*n*-butylammoniumtriphenylfluoborate should be in the singular (p. 157), whilst the use of the " acid-base " terminology of G. N. Lewis (p. 166) is to be deplored since if boron trifluoride is an acid then argon (p. 41) is a base !

The monograph will greatly facilitate investigations in the field by eliminating the laborious task of ploughing through abstracts of the literature ; and the co-operation of several American industrial organisations, in placing at the authors' disposal material contained in patents and unpublished work from their own laboratories, has added considerably to the value of the book. The last two chapters dealing with methods of handling and analysis are extremely useful, whilst the detailed method for analysis of fluoboric acid (p. 233) has been developed by a company and is not available in the literature. The book should surely find a place in every reference library.

<div align="right">C. W. SHOPPEE.</div>

Introduction to Radiochemistry. By GERHART FRIEDLANDER and JOSEPH W. KENNEDY. [Pp. xiv + 412, with 41 figures.] (New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1949. 40s. net.)

THE use of radioelements as " indicators " or " tracers " has been introduced into hundreds of scientific, technological and biological laboratories. The principle of the method is simple and generally known and the active material, not so long ago difficult to procure, is now easily obtainable ; if, nevertheless, many research workers who could benefit from this new and powerful method are still slow in adopting it the reason frequently is that it demands aquaintance with scientific and technical details which are not contained in the standard textbooks of physics and chemistry.

The best way to acquire this necessary knowledge is participation in an instruction course specially designed for the purpose. The two authors of the book have been giving such courses for several years and are now presenting the essence of their teaching in print. Their book gives much more than the title indicates. Convinced that an intelligent use of radioactive tracers requires sound knowledge also of the physical side of the subject, they devote several chapters to such topics as Nuclear Structure, Energetics of Nuclear Reactions, Sources of Bombarding Particles and the description of Measuring Instruments. Even the historical development of the subject is not neglected. (There is a slight inaccuracy in the description of the discovery of isotopes of the non-radioactive elements : J. J. Thomson's and Aston's observations originated from experiments with " rays of positive electricity " which were undertaken independently of the simultaneous developments in radiochemistry.)

A very useful chapter deals with the statistical character of radioactive disintegration, which in Schweidler s day was only of theoretical importance, but now, after the development of methods for the detection of single disintegrations, has become of great practical significance for radioactive measurements. At the end of each section of the book a number of varied exercises and a list of references for further reading are to be found ; an appendix contains a complete list of all nuclides known up to February 1949,

followed by a table of nuclear cross-sections for activation by thermal neutrons, and one of physical constants and conversion factors.

The book is obviously the fruit of years of specialised experience and will be welcomed by all who have to conduct similar courses ; they will be able to recommend to their students an up-to-date textbook for use during the practical instruction. However, the book will appeal to a much wider circle of readers, for in spite of its moderate size and modest title it is quite comprehensive. It will be found invaluable not only by students but also by research workers in radiochemistry and allied fields.

F. A. PANETH.

Frontiers in Colloid Chemistry. Edited by R. E. BURK and O. GRUMMITT. Frontiers in Chemistry, Vol. VIII. [Pp. x + 157, with 54 figures.] (New York and London : Interscience Publishers, Inc., 1950. 32s. net.)

THIS volume, the last of the series "Frontiers in Chemistry" published from lectures given annually at Western Reserve University, U.S.A., is based upon six lectures delivered in 1945 by five different contributors. In a rapidly expanding subject it would seem a matter for regret that five years should elapse before publication. However, some effort has been made to bring the subject matter up to date (e.g. chapter on Adsorption) and the book is therefore of considerable value now.

In common with most collaborative works, it would appear that the different contributors do not have quite the same type of reader in mind. H. S. Taylor's excellent chapter on the role of Adsorption in Colloid Science gives a general account of adsorption phenomena, leading from simple models and Langmuir's treatment to the more complex modern ideas on heterogeneity of surfaces. Difficult mathematical derivations are omitted, though important results and their physical implications are considered. H. H. Strain contributes a detailed, non-mathematical account of chromatographic Adsorption Analysis, but certain portions lack precision of argument and statement. R. J. Myers's chapter on Ion Exchange with special reference to Synthetic Resins is a very complete, clear presentation of a new and important field. In the short chapter on Sedimentation, V. R. Daverell reviews some of the lesser-known and unusual aspects of sedimentation, and, omitting as it does the more established work, this chapter is suitable only for the experts in the field. J. W. McBain, in two chapters on Colloidal Electrolytes and Organisation of Crystals and Micelles of Soap respectively, covers these subjects very generally from first principles. These treatments are very much from the author's personal viewpoint, which is not shared by some active workers in the field.

The book is well produced and each chapter provides a useful bibliography. At two-thirds of the published price the reviewer's recommendation would have been strong.

PALEY JOHNSON.

Deformation and Flow. By M. REINER, Dr. Techn. [Pp. xx + 346, with 94 figures, including 2 plates.] (London : H. K. Lewis & Co., Ltd., 1949. 32s. 6d. net.)

THE desire for an exact knowledge and understanding of the mechanical behaviour of the wide variety of industrial materials in common use today

has given a new impetus to the study of rheology, and the present book by so eminent an authority is a particularly useful tool for investigators working in materials-testing laboratories. Although the author calls it an elementary introduction to theoretical rheology, it is elementary only in the sense that the mathematical treatment is by vector analysis and the use of tensors has been avoided. In many respects this is an advantage, in that the argument can be followed by those who are not necessarily mathematicians. Although the book is theoretical, numerical examples are given of the application of theory to such problems as viscosity, plastic flow, strain hardening and creep.

The whole field of rheology has been surveyed from the point of view of the classical physicist ; the molecular make-up of matter has not been considered except where molecules can be treated as ordinary bodies of small dimensions. Rheology is a complicated subject and few materials have simple rheological properties. The author has followed a logical and systematic approach, dealing first with flow properties of liquids and solids, then with elastic properties and volume flow. He has had the advantage of intimate contact with many of the rheologists who have made substantial contributions to the advancement of the science and the book is of particular interest in giving reference to those who have established well-known laws but whose names are seldom quoted, such as Hagen and Margules. The aim of the science of rheology is to express the mechanical behaviour of materials in terms of fundamentals. It is the exception, however, for a material to possess only one simple fundamental property ; it may show both solid and liquid behaviour according to the test conditions. Creep of concrete, for example, is a matter of considerable practical importance and it may come as a surprise to many to learn that, as shown by Glanville and Thomas, if it has a yield stress its value is negligible and that for practical purposes the creep is proportional to the applied stress. This is a characteristic property of viscous flow. Reiner's approach is to define a number of ideal types of simple rheological behaviour of any actual substance. These ideal types include the Hookean Solid, the Newtonian Liquid, the Kelvin Solid, the Maxwell Liquid, the St. Venant Body, the Bingham Body. This terminology, together with the systematised notation used in the mathematical arguments, is much to be commended. It is all the more surprising therefore to find in such a logical system the expression " Generalised Newtonian Liquid " used for a liquid that is " Non-Newtonian."

Special reference has been made to the phenomenon of " volume-flow " and its explanation in terms of void content of the material. The subject has a close bearing on the measurement of strength and possibly on the difference between strengths calculated from atomic forces and strengths actually measured.

An exact knowledge of the stresses operating within a material is necessary for the calculation of any fundamental rheological property. Reiner deals with this subject of stress analysis in detail and most of his arguments can be followed without difficulty, although his condensed style requires concentrated attention. One may ask therefore why he does not deal with the apparent anomaly arising from the two methods of approach to the tensile test for measuring flow properties. By the methods of tensor analysis the effective shear stress in the material is one-third of the tensile stress, whereas by the Mohr circle analysis the maximum shear stress on the 45-degree plane is one-half the tensile stress.

It is clear that rheology today is essentially a practical subject, the theory

of which is still ever trying to catch up with the newly discovered behaviour of real matter. The book is well set up and each chapter is clarified by a summary of its findings.

A. R. LEE.

Physical Methods of Organic Chemistry. Technique of Organic Chemistry, Vol. I. Second completely revised and augmented edition. Editor : ARNOLD WEISSBERGER. Part 1 [pp. xii + 1–1072, with 395 figures]. Part 2 [pp. xii + 1073–2096, with 356 figures]. (New York and London : Interscience Publishers, Inc., 1949. 100s. net each part.)

THIS comprehensive treatise on the physical methods of organic chemistry is the second edition of a work which was first published some five years ago and is designed to provide authoritative accounts of the numerous physical methods necessary in present-day organic chemical research work. In addition to the experimental treatment, the book sets out to give the theoretical background of the various methods and sufficient information to enable the chemist to make a critical evaluation of his experimental results. The first edition however was open to the criticism that it varied considerably in the thoroughness with which the various subjects were treated, a fault which was almost inevitable in a large book where nearly every chapter was written by a different author. Such defects as there were largely have been overcome in the present work, which has been enlarged by the addition of five new chapters (on temperature measurement, temperature control, determinations of vapour pressure, determinations with the ultracentrifuge and electrophoresis) and by the substantial enlargement of several of the other chapters (e.g. addition of sections on electron microscopy, nephelometry and the determination and evaluation of light scattering). Six other chapters have been entirely rewritten and the remainder revised so that the whole work now presents a more balanced treatment of the subject. The volumes are a contribution of the first order to the scientific literature ; in the space of over 2000 pages, the 31 chapters deal with the whole range of physical methods from every aspect, and indeed the theoretical and experimental treatment of the various methods would each form an authoritative survey. The important sections on the interpretations of spectra, polarography and X-ray diffraction data are still too brief to be of substantial value to the organic chemist and rather inadequate reference is given here to more authoritative works.

Apart from the new chapters already mentioned there are accounts of determinations of melting and freezing temperatures, boiling and condensation temperatures, density, solubility, viscosity, surface and interfacial tension, parachor, properties of monolayers and duplex films, osmotic pressure, diffusivity, calorimetry, microscopy, crystallochemical analysis, X-ray diffraction, electron diffraction, refractometry, spectroscopy and spectrophotometry, colorimetry, photometric analysis, fluorimetry and turbidimetry, polarimetry, dipole moments, conductometry, potentiometry, polarography, magnetic susceptibility, radioactivity and mass spectrometry.

The books are very well illustrated throughout with innumerable clearly presented diagrams of apparatus as well as many graphical illustrations of physical properties, and experimental results. The mathematical treatment is not excessive and here again the point of clarity of presentation must be

made. Being an American production it is understandable that most of the specialised apparatus described is obtainable only from American firms and there is little mention of the British market. It is difficult to overestimate the importance of these volumes and no chemical research library can afford to be without them.

A. W. JOHNSON.

Advances in Protein Chemistry. Vol. V. Edited by M. L. ANSON and JOHN T. EDSALL. [Pp. x + 481, with 35 figures.] (New York : Academic Press, Inc., 1949. $7.50.)

THIS series maintains its high standard, and the diversity of subjects covered by the present volume is such that few whose interests are directed to proteins will fail to find something to attract. One general criticism, perhaps worthy of mention, is the delay of nearly two years (as indicated by several footnotes) between writing and publication. Though this does not greatly detract from the value of articles covering many years' work, it is a considerable handicap in other fields where developments are rapid. The increasing use of addenda seems to be hardly a satisfactory solution for an annual publication and the reduction of this lag should be possible.

The practical importance of proteins is stressed more this year than in earlier volumes, nutritional value, tanning and protein fibres being included among the subjects reviewed. J. B. Allison, in discussing the evaluation of proteins in nutrition, brings out the difficulties inherent in methods based on nitrogen balance, growth, tissue regeneration and amino acid analysis. H. P. Lundgren writes of synthetic protein fibres and the physical and chemical studies of protein structure which have made their production possible. This comparatively recent development in textiles is already of importance and its extension may in turn contribute to the understanding of natural fibrous systems. Different aspects of fibrous proteins are discussed in K. H. Gustavson's article on tanning and the theoretical basis, for the action of the principal tanning agents on hides, is reviewed.

The chapter on milk proteins is confined to a discussion of the physical and chemical properties of the individual proteins, no attempt being made to relate them to each other. Muscle is one of the few protein systems in which this type of integration has been attempted, but an explanation of the relative proportion and structural variation of proteins in comparatively inert mixtures, such as milk, must one day be sought. A more heterogeneous collection of proteins, those from plants, has been considered by J. W. L. Lugg, who has placed a wide interpretation on the title, and has included the metabolism as well as the chemistry of these compounds. The breadth of treatment adds considerably to the interest of this chapter.

Perhaps of greatest attraction to the chemist are the comprehensive chapters on peptide synthesis by J. S. Funton and on amino acid composition of proteins by G. R. Tristram. Interest in the former subject has been greatly stimulated by the discovery of increasing numbers of biologically active peptides, and the present review is both adequate and timely. The usefulness of Dr. Tristram's article is greatly increased by the inclusion of many tables in which all the satisfactory analytical data available at the time of writing have been collected and presented in a most clear and accessible form.

The last and shortest article by A. Claude places the protein constituents of cells in relation to the other major constituents and to the whole as a living

unit. This approach is in contrast to the rest of the volume and it is to be hoped that such functional studies will come into greater prominence as improving techniques facilitate their development.

R. R. P.

Advances in Food Research. Vol. II. Edited by E. M. MRAK and GEORGE F. STEWART. [Pp. xiv + 558, with 139 figures.] (New York : Academic Press, Inc., 1949. 66s. 6d. net.)

THIS volume maintains a high standard throughout, presenting reviews of fundamental and applied research on nine subjects of widely differing nature, but all relevant to the food industry. The numerous references following each section contain a proportion derived from other than United States sources. In general, the reviews have a value above that of a mere collection of abstracts, are interesting to read and are stimulating of further thought.

Ion-exchange includes a valuable section on laboratory applications, in addition to a description of ion-exchange materials, of the theory underlying their use and of practical examples of their application to the removal of ionisable material in food processing. *Thermobacteriology* designates the study, in the widest sense, of the effect of heat on bacteria. The mathematical principles used in evaluating thermal processes and the difficulties involved in the determination of thermal death time are fully discussed. *Quarternary ammonium compounds* are well documented, but the value of the review would have been greater if the author had applied a more critical judgment and had included an account of the less favourable reports on these compounds. A surprising omission is any reference to the work of McCulloch *et al.* (*Amer. J. Pub. Health*, **38**, 4, 493, 1948), with its convincing explanation of the mechanism of reaction, accounting for many inconsistencies in reported work. *Pharmacology of DDT* contains a detailed summary of published work on the acute toxicity of DDT and some information on its chronic toxicity and its passage via herbage and ruminants into food products.

Analysis of foods by sensory difference tests reviews the limitations, the application and the development of standardised tasting tests. *The chemistry of fruit and vegetable flavours,* although restricted in its value by the paucity of available information, is a balanced survey of the known facts : the omission of vanilla is, however, surprising, as it is the most popular of the fruit flavourings. *Histological changes induced in fruits and vegetables by processing* is a well-illustrated, valuable and unusual fundamental treatment of the effect of processing on living cells. With the exception that the work of M. Friess is omitted, the bibliography is very full. *Spoilage of fish and its preservation by freezing* treats comprehensively the bacteriology of fresh and of spoiling fish, the biochemistry of spoilage, the estimation of fish quality and its practical control. *Spray drying of foods* covers in detail the design of equipment and the engineering involved, both from the theoretical and the practical aspect.

From the staff of the Laboratories of J. LYONS & CO., LTD.

Chemical Constitution and Properties of Engineering Materials. By P. C. CARMAN, M.Sc.(N.Z.), Ph.D.(Lond.). [Pp. xii + 894, with 236 figures.] (London : Edward Arnold & Co., 1949. 50s. net.)

MANY attempts have been made to cover the chemical aspects of constructional materials, but the subject is so intricate and detailed that they have

either been of an elementary and introductory nature or else a collection of large and undigested bibliographies. The former have little practical value and the latter mean considerable research into the literature before much use can be made of them.

The author has brought a mathematical mind to bear upon this tangled mass of facts and has tried to classify them in some logical manner. His main stress is therefore on the subjects of crystal structure, strength of materials, phase rule representation, of binary alloys, electro-chemical corrosion theory, the structure of silicate materials and the properties of high polymers.

Against this background are detailed the properties of carbon and alloy steels, cast irons, non-ferrous metals, clays and ceramics, refractories, cements and glasses, resins, rubber, cellulose and protein derivatives. The book also contains chapters on solid, liquid and gaseous fuels and water treatment. Each chapter is followed by a selection of some 20–50 references, which be followed up by those wanting more information.

The author has spread his canvas wide and has filled it in with great detail with a result that it must only be read in small doses. It is in this respect that perhaps the text could be improved by more emphasis on the fundamental points, and deletion of material which is not required for subsequent use in the book or which is already more fully dealt with in a textbook on that subject where the need for condensation is not so pressing.

Both the author and the publishers are to be congratulated on producing a book which should find wide use in the world amongst chemical engineers and those whose work requires an intimate knowledge of the chemical behaviour of materials of construction.

M. B. DONALD.

Metal Finishing Handbook. By P. A. CARTWRIGHT, A.M.G.I., M.I.E.I., L.I.M. [Pp. xii + 216, with frontispiece and 32 figures.] (London and Glasgow : Blackie & Son, Ltd., 1950. 15s. net.)

ALTHOUGH it can trace its descent from Faraday, much of the electroplating industry, with which this book is chiefly concerned, is operated as a craft rather than a science. It is true that scientists control the modern installations for electroplating components on a mass-production basis, but the small jobbing plating shops – which are legion—depend more upon the skill of the plater than on any scientific control. In recent years attempts have been made to rectify this state of affairs by providing courses in electrodeposition, so that young men in the industry can learn the scientific principles upon which their industry is based and apply them in their daily work. Such students will inevitably be attracted to the volume under review. It is published by a reputable firm ; its layout, printing and illustrations create a favourable impression, and last, but probably not least, the price is reasonable judged by present standards. It is, nevertheless, most important that this book should not come into the possession of students, for it contains far too many errors and is much too likely to lead inexperienced platers astray.

Some of the errors may be just slips overlooked in proof correcting, as, for example, the statement on p. 20 that ferrous sulphate is used in the pickling of steel, but there is no excuse for mistakes in reporting information taken from British Standards. A notable example of the latter type of error is provided by the descriptions given on pp. 160 and 168 of the B.N.F.

jet test of deposit thickness. Not only is the method of performing the test wrongly described, but the solution given on p. 160 would not work with coatings of four of the five metals for which it is said to be satisfactory. Indeed, this particular method is not advocated for chromium at all, although the author appears to think otherwise.

In many respects the author appears to be out of touch with modern plating practice. Thus on p. 17, no reference is made to the phosphate, metasilicate and emulsion-type cleaners, and the method for plating aluminium given on p. 90 has been largely superseded by the zincate process, to which only passing reference is made. Nickel plating is an important branch of metal finishing and the reader could reasonably expect to find in this handbook precise information which would enable him to produce either bright or dull nickel coatings. The general principles of bright nickel plating are discussed in a woolly and inaccurate fashion on p. 63, but no bath composition is given. For dull nickel plating, on the other hand, no fewer than seventeen compositions are given, most of which are likely to have similar characteristics. In view of this it is not surprising that the author gives no information as to the conditions under which the individual baths are to be preferred, but the reader may well feel bewildered.

Numerous other examples of errors and defects could be quoted, but those given are probably sufficient to indicate the unsatisfactory nature of this book.

A. G. QUARRELL.

BOTANY AND AGRICULTURE

Anatomy of the Dicotyledons. Leaves, Stem and Wood in relation to Taxonomy, with Notes on Economic Uses. Vols. I and II. By C. R. METCALFE, M.A., Ph.D., and L. CHALK, M.A., D.Phil., with the assistance of M. M. CHATTAWAY, C. L. HARE F. R. RICHARDSON, E. M. SLATTER. [Pp. lxiv + 1500, with 3 plates and 317 figures.] (Oxford: at the Clarendon Press, 1950. 126s. net.)

IT was in the early eighties of the last century that Radlkofer, who togetl with Vesque was mainly instrumental in demonstrating the advantages be derived from the use of anatomical characters in the classification flowering plants, made the pronouncement that " the next hundred yo will be devoted to the anatomical method." Even though this prophe has not been entirely fulfilled, there can be no doubt that, in the sixty-o years that have elapsed since then, taxonomists the world over have accept the fact that anatomical features may play an all-important part in t determination of sterile material and that they may commonly be decis in elucidating affinities where the external vegetative and floral featu alone do not suffice. The impressive work by Metcalfe and Chalk, tl forms the subject of this review, is indeed the best testimony to the imp tance attached to the study of plant anatomy on a taxonomic basis. Ap from its great value from the purely systematic point of view, its practi applications in relation to medicinal and other plants in economic use,

The greater part, occupying upwards of 1300 pages, of the two volumes is devoted to the detailed description of the anatomical features presented by the families of Dicotyledons, and for this the reviewer has little other than whole-hearted praise. The general arrangement follows closely that of Solereder's *Systematic Anatomy of Dicotyledons* (1908), from which indeed some of the matter and part of the illustrations are derived, but those who are familiar with the extensive collections of sections lodged at Kew and at the Imperial Forestry Institute, Oxford, will realise how much new effort on the part of the authors has gone into the preparation of this work. There are many additional full-page illustrations, comprising in particular diagrams of stem and petiole structure. The use of special type to pick out the various structural features in leaf and axis affords a book that is consulted with ease. The presentation is more balanced than in Solereder's book, since minor details of doubtful importance have been omitted and diverse features, such as petiole structure, receive more attention. A good deal of space might have been saved, and the cost of the work lessened, by a judicious use of abbreviations.

A preliminary summary of the more important anatomical characteristics of a family is, as in the old Solereder, usually followed by detailed descriptions of the features of leaf and axis. Innovations are constituted by an additional section containing a discussion of the bearing of the special anatomical characteristics of the family on its classification and affinities, and one dealing with economic uses as far as the vegetative organs are concerned. In the description of the axis " young stem " and " wood " are dealt with separately, but the distinction is somewhat elusive, as there is no clear definition as to what is understood by young stem ; in the case of arboreal plants the data probably for the most part refer to twigs. The details given under wood, which are provided by the second author, supplemented by data collected by Chattaway for the genera in the Yale collection, appear mainly, if not entirely, to be based on studies of timber. The inclusion of these data constitutes a most valuable addition to the scope of the book and represents the outcome of many years of laborious investigation, but it is perhaps open to question whether they should not have been published in a separate work. Some thirty pages at the end are devoted to an enumeration of the families in which the principal anatomical characteristics of leaf and stem are to be found. One feels that some form of key might have been more helpful to those using the book. The bibliography, with 2512 references, includes a considerable number of papers that refer to general rather than to systematic anatomy.

The authors state in their preface that their object has been to emphasise the taxonomic and phylogenetic value of histology, although it is hoped that the book will be useful also to those interested in other aspects of the anatomy of Dicotyledons. Of its great use as a work of reference there can be no doubt, but it will hardly satisfy the needs of the student of comparative anatomy. For this, the general account at the beginning is all too brief and the details of developmental anatomy all too scanty. The introductory section might well indeed have been expanded to afford more guidance to the novice by more descriptive detail of the features involved in the study of systematic anatomy. This applies, for example, to the consideration of secretory elements and of anomalies in the vascular structure of the axis, while the references to types of vessel pitting on p. xlvi will scarcely be comprehensible to anyone not rather fully conversant with wood anatomy.

In this connection a glossary explaining the numerous terms that are necessarily employed, with references to illustrations, would have been very valuable. One misses in the introduction a consideration of the possible importance of vascular organisation in the herbaceous plant suggested by the work of Dormer on Leguminosæ. The section on " Anatomy and Phylogeny " contains a valuable exposition of the phylogenetic evidence to be gleaned from wood anatomy, but some of the other matter in this section might have been curtailed. It is difficult to get away from the feeling that an attempt has been made to make the book serve too many purposes. The occasional references to ecological anatomy, which are to be met with in the course of the work, would better have been assembled collectively in the introductory section than inserted rather promiscuously among the other matter. For instance, it is strange to read on p. 148 under Caryophyllaceæ that " the amount and distribution of palisade tissue sometimes varies within a species according to the nature of the illumination," when such a remark could be applied to the representatives of many other families.

The various criticisms that have been made in the course of this review do not detract from the great contribution made by Metcalfe's and Chalk's work to our knowledge of the anatomy of flowering plants. The work is one that will be welcomed by and prove to be indispensable to all who are interested in plant structure.

<div align="right">F. E. FRITSCH</div>

Plant Pathology. By SIR EDWIN J. BUTLER, C.M.G., C.I.E., D.Sc., M.B., LL.D., F.R.S., and S. G. JONES, D.Sc. [Pp. xii + 979, with 435 figures.] (London : Macmillan & Co., Ltd., 1949. 63s. net.)

IT was known before the last war that Sir Edwin Butler was engaged, in collaboration with Dr. S. G. Jones, on a revision of his book *Fungi and Disease in Plants*, published in Calcutta in 1918. Because of his heavy official duties, Sir Edwin agreed to re-write only the section on general principles, Dr. Jones undertaking the section on selected diseases, in which—on this occasion—diseases of British crops were to be substituted for the tropical diseases dealt with in the earlier book. The present book, therefore, is a completely new work, retaining only the well-proved ground plan of its predecessor. Owing to the death of Sir Edwin in 1943 it has fallen to Dr. Jones to pilot the book through the press.

As was perhaps to be expected from so long a delay in publication, there were some who prophesied that the book would be out of date before it appeared. Certainly there is no reference to some of the most recent advances in knowledge, but this is a relatively minor matter in a book of this type. The book is essentially a textbook of plant pathology, designed to set before the student the established principles of his subject, together with descriptions of specific diseases, intended partly to illustrate the principles, and partly to give the student the necessary groundwork for a study of the main plant diseases he may encounter in agriculture, horticulture and forestry.

There is no doubt that there was a real need for a book of this type in the teaching of plant pathology in universities. The discussion of principles separately from diseases has many advantages for the student, and such general subjects as host-parasite relations, morbid anatomy and histology,

and the principles of the control of plant disease are dealt with better in this book than in any other English-language text. The descriptions of specific diseases are very full and include a review of all the important literature until about 1945. For university work here the book has the added advantage of dealing with a number of diseases that are important in Europe, but that are often omitted from American texts. The new book will therefore be warmly welcomed by plant pathologists in Britain. Occupying nearly 1000 pages its price is high for most students, but it is very well produced and illustrated by good photographs and many detailed line drawings by Dr. Jones.

While giving an unreserved welcome to the book as meeting a long-felt want, one cannot help feeling that it marks the end of an era—certainly a very productive era—rather than the beginning of a new one. The reason for this is that, although the book contains chapters on virus diseases and deficiency diseases, it is essentially mycological in its outlook. Until some twenty years ago practically all plant pathologists were mycologists, and admirable work was done in the laboratory and in the field in working out the life histories of the fungi causing plant disease. It was probably L. R. Jones of Wisconsin who did more than anyone else to initiate a new phase—the experimental study of the effect of environmental conditions on host-parasite relationships. Since then have grown up the specialised schools studying virus diseases, deficiency diseases, fungicides, etc. Most of this is well and faithfully recorded in the new Butler and Jones, but often as if seen through the eyes of a mycologist. A more dynamic view of plant pathology is to be obtained from a much smaller recent book—Bawden's *Plant Diseases*.

In a book of this size there are bound to be parts somewhat less satisfactory than others. In the descriptions of some of the diseases, more especially virus and deficiency diseases, the authors have not always been able to appraise the relative importance of the various contributions to the literature in the way that an active worker in these subjects would have been able to do. For example, in the section on Grey Speck of Oats a number of rival theories are recorded, and the student is left to judge for himself between them; also, there is no mention of some of the more significant chemical studies on factors governing the availability of manganese in the soil, which are all-important in determining the incidence of the disease in the field. Similarly, the section on the nature of viruses gives a very inadequate picture of the developments of the last ten years and there is not even one electron microscope photograph of a virus.

These, however, are minor points in a book which will be a most valuable text for students as well as a useful reference work for practising plant pathologists.

G. GRAHAM SAMUEL.

Advances in Agronomy. Vol. I. Edited by A. G. NORMAN. [Pp. xii + 439, with 19 figures.] (New York : Academic Press, Inc., 1949. $7·50.)

AGRICULTURAL science covers so wide a field and trenches on so many other branches of science that its students have considerable difficulty in keeping themselves informed of progress made outside their own Institutes. The difficulty is mitigated for workers in the British Commonwealth by the

publications of the Commonwealth Agricultural Bureaux ; nevertheless, short monographs by recognised experts are always welcome.

The American Society of Agronomy has set out to supply this need by a new series of volumes, which it may be hoped will become periodical. The Editor is Dr. A. G. Norman, formerly of Birmingham University and Rothamsted, who has since had a distinguished career in the United States ; as might be expected he has done his task well and this volume will add to his laurels. The contributors are all workers in North America ; twelve are in the United States and one in Canada ; the work reviewed is largely American, but it is intended in later issues to cast the net more widely. Each contribution is a separate little monograph with a good bibliography. Some of the chapters, e.g. those on soil micro-organisms and plant roots, on clay minerals in soils and on fixation of soil phosphorus, will be of interest to many others besides agriculturists.

The recent Rothamsted work on soil micro-organisms and on the relation of the clover plant to the nodule organism could usefully have found a place, as could Drs. E. M. Crowther's and F. Yates's valuable discussions of fertiliser results and practices in this country. The fixation of phosphorus by the soil is well treated by L. A. Dean : it is of great practical importance and costs the United Kingdom and North-Western Europe vast sums of money each year. Phosphatic fertilisers are used by our farmers in enormous quantities, yet barely a quarter of the added phosphorus reaches the plant : the rest is " fixed " by the soil and remains useless so far as is known. Recent knowledge of the composition and structure of clay gained by the use of X-ray and other methods has revolutionised soil science : J. E. Gieseking sets out the results clearly and illustrates them by means of diagrams. The confused mass of data laboriously accumulated in regard to ionic exchanges and replacements is gradually being brought into order and those who have not been able to follow recent literature will read this summary with interest. Weed control by chemical methods is described by A. G. Crafts and W. A. Harvey, who set out a good deal of the present-day knowledge of this rapidly changing subject. Hitherto weed destruction has been effected by cultivation processes often costly and laborious : if it can really be done as well by spraying with 2–4 D (2 : 4–dichlorophenoxyacetic acid) and similar chemicals, considerable changes in agricultural procedure become possible. The basis of the method is that these substances are selective, killing some plants and not others : cereals are less affected than some of the common weeds, e.g. charlock, that often accompany them. Spraying is now widely done on contract, which is the safest way of carrying out so new an operation. More specialised chapters deal with potatoes, lucerne and soya beans. The area under potatoes in the United States has fallen, but yields have increased so much that the total output has risen. English readers will have some difficulty in following the results, as they are expressed in bushels and not tons per acre and nowhere is a conversion factor given ; adopting the usual value of 60 lb. per bushel the 1919–24 yields averaged 2·7 tons per acre and the 1943–48 yields 4·5 tons per acre compared with the English average of 7·1 tons per acre. Wide differences in cultivation and fertiliser practice account partly for the results, but climatic factors are probably those chiefly involved.

The volume will be cordially welcomed by agricultural experts and its successor will be awaited with interest.

E. John Russell.

3 D

Introduction to Soil Science. By G. W. LEEPER, M.Sc. (Melb.). [Pp. viii + 222, with 12 plates and 37 figures.] (Melbourne : Melbourne University Press, 1948 ; London : Cambridge University Press, 1950. 21s. net.)

THIS book is written to give a concise account of soil science and to do so primarily for Australians. So far as one without direct contact with the soil problems of Australia can judge, the author renders good service to soil students in that Dominion, but the book certainly claims attention outside Australia and should be very valuable in all countries as an introduction to the subject.

There are three parts. The first 64 pages describe the soil profile and the soil type, the classification of soils, the making of soil maps and the processes of soil formation. Good use is made of the soil survey work carried out in Australia and the distribution of Australian soils is clearly described. There is a brief but useful reference to older methods of classification.

Part 2, nearly 60 pages, deals with soil physics. There is an emphasis throughout on the physical conditions of soil in the field ; and this is important, for the study of the physics of soil material in the laboratory alone can lead one far away from a knowledge and understanding of field conditions. The difficult subject of the movement of soil water is dealt with very well.

Part 3, covering a little over 70 pages, deals with soil chemistry. It presents a good account of the constitution of the soil and of its reaction, and of the chemical activities of the constituents of soils and of those of fertilisers added to the soil. There is a useful chapter on erosion.

The appendix contains a diverse collection of notes (many of them on practical matters of the field and the laboratory) which could not be introduced into the text.

The book is written in a good and attractive way, and it is well illustrated. The author does not hesitate to express a personal opinion here and there, but does so without in any way obfuscating generally accepted views. The book should prove very useful, not only in Australia, where it obviously has special value, but among soil students generally.

N. M. C.

Soils : Their Physics and Chemistry. By A. N. PURI, D.Sc., Ph.D. [Pp. xviii + 550, with 61 figures.] (New York : Reinhold Publishing Corp. ; London : Chapman & Hall, Ltd., 1949. 56s. net.)

THIS book is in three parts. Twenty-four chapters deal with the Chemistry of Soil, fifteen with the Mechanical Analysis of Soil and seventeen with Soil Moisture. It gathers together a great deal of useful and valuable information and data which many soil students will be glad to have. As a textbook for beginners and for the student of agriculture (which the author tells us he intends it to be) it does, however, seem to lack perspective—to give too much detail and emphasis in dealing with some parts of the subject and to neglect other parts. The description of apparatus and of methods, and also some of the tables, would be more appropriate in a laboratory manual than a textbook.

Dr. Puri, while acknowledging " equally important " work by others, states that he draws mostly upon his own work " to avoid controversial topics." He could well collect and publish, as such, his own very consider-

able researches, but it is difficult to see how one man's work can be the basis for a textbook presentation, or why one man's work should be differentiated as non-controversial. Moreover, the author tells us that "facts have been stated and theories left in the background." But could the subject be described in this way if, as is claimed, it is to be shown as a science capable of yielding generalisations ? And if the book is essentially a statement of facts, why does the author say that some scholars may disagree with his views ? Theories are not, in fact, avoided although generalisations are apt to be obscured by practical and factual detail.

Perhaps the most important matter for a reviewer's comment is the almost complete absence from this book of the study of the soil as a natural object, the differentiation of its parts under the influence of climate and of cultivation. The book really concerns the physics and chemistry of soil *materials*—not soils—and with this omission it is difficult to show, in accordance with the author's claim, that soil science is an independent science as distinct from the haphazard study of its materials. It is to be hoped that the pedological aspect of the subject can be developed in the future editions of a book which already presents a wealth of study of soil material.

<div align="right">

N. M. C.

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PHYSIOLOGY AND BIOCHEMISTRY

The Human Body and its Functions. By C. H. BEST, C.B.E., M.D., D.Sc., F.R.S., and N. B. TAYLOR, V.D., M.D., F.R.S. (Canada). Second edition. [Pp. xii + 500, with 8 coloured plates and 363 figures.] (London : Chapman & Hall, Ltd., 1949. 18*s*. net.)

THIS is an excellent elementary textbook of Human Physiology, lucidly written and attractively presented with a wealth of excellent illustrations and several coloured plates. It is a scaled down version of the somewhat larger volume *The Living Body* by the same authors, which was itself derived from their monumental textbook of physiology for medical students. The present book will undoubtedly receive the warm welcome which it deserves from students in fields such as Nursing, Physio-Therapy and Physical Training, who need to acquire some knowledge of human physiology with the minimal grounding in the basic sciences.

I must confess, however, that over and above its solid excellence as an elementary presentation of the facts of human physiology, I found it, as indeed I find the two larger volumes in this series, rather uninspiring. It is sound, nourishing stuff but it does not whet the intellectual appetite. There is no comparison, for instance, between it and Amberson and Smith's *Outline of Physiology*, which is just as elementary in general treatment, but quite fascinating reading. Partly for this reason and partly because the general style of the work is that of the conventional textbook, I doubt whether it will, at any rate in this country, succeed in attracting the class of reader for whom (says the dust-cover announcement) it is primarily intended--the layman rather than the medical student. Writing about a highly technical subject, whether it be physiology, physics or any other science, for the layman is an exceedingly difficult thing to do successfully and it certainly cannot be done simply by producing an elementary textbook. From this point of view, the omission of all but passing references to the stories behind great discoveries, in which physiology abounds, is a serious defect, although no doubt dictated by considerations of space.

However, despite these special criticisms the book as it stands is a first class elementary text for the many students who must acquire a sound knowledge of modern physiology, but who do not intend to pursue the subject much further.

R. A. G.

Hæmoglobin. A Symposium based on a Conference held at Cambridge in June 1948 in memory of Sir Joseph Barcroft. Editors : F. J. W Roughton and J. C. Kendrew. [Pp. xii + 317, with frontispiece and numerous other illustrations.] (London : Butterworth's Scientific Publications, 1949. 40s. net.)

Joseph Barcroft made great contributions to many fields of mammalian physiology, and the last years of his life were mainly devoted to the study o foetal metabolism and of ruminant nutrition. But probably his mos important contributions were concerned with the respiratory function o blood and the properties of hæmoglobin, fields which will always be associated with his name. Barcroft's greatness showed itself in a directness of ments and experimental approach and this makes even now the reading of hi papers and books a delightful occupation. Barcroft's influence was fel widely beyond the circle of his students and collaborators. It was therefor fitting that tribute should be paid to his memory by holding an internationa conference on hæmoglobin.

The book which is a record of the proceedings of this conference is divide into two parts. The first part, relatively small in size, contains eight persona and largely biographical appreciations of Sir Joseph Barcroft by form colleagues. Taken together they give a very good picture of Barcroft' personality. One feels, however, that a more complete appreciation of hi contribution to physiology and a bibliography of his writings would no have been out of place. The second part of the book consists of twenty eight articles on various aspects of the physics, the physical chemistry an the biology of hæmoglobin and myoglobin.

The variety of approaches and techniques described is an apt illustratio of a general development in biochemistry and physiology. The almost com plete separation of the various sciences which was so characteristic of th Victorian and Edwardian era is breaking down and the use of magneti methods or of electronic concepts in studies on hæmoglobin is now generall accepted as providing information of importance to the biologist. The use o such diverse methods renders frequent consultation and discussion betwee workers in different fields particularly desirable and emphasises the valu of conferences such as this on hæmoglobin.

Many of the contributions are concerned with a review or summary o work published elsewhere. But even with such papers the discussion i almost always illuminating and stimulating. Other papers contain mostl material hitherto unpublished. The standard of the individual contribution is almost universally high. Of particular interest is the work of Peruts an Kendrew on the X-ray crystallography of hæmoglobin and myoglobin respec tively and the general account given of the methods used for analysin complex crystal structures by means of X-rays. Other papers of grea interest are those of Roughton and his colleagues on the kinetics of th combination of hæmoglobin with oxygen and carbon monoxide, papers o amino-acid composition and on terminal amino groups by Tristram an Sanger respectively, and a number of contributions dealing with the spectr

photometry of hæmoglobin and its derivatives by Drabkin, Jope and others. Pauling discusses the electronic structure of the iron-porphyrin linkage and Wyman produces strong evidence for the thesis that the four hæms occur in pairs with strong interactions between members of the same pair and weaker interaction between members of different pairs.

The contribution of Rimington on the biosynthesis of hæm represents a stimulating speculation, though some of his detailed assumptions have not been verified by more recent experimental work.

The book represents a most useful and interesting survey of very many aspects of the properties of hæmoglobin. The production is good and printing errors are few. The authors and editors have rendered a useful service to the increasing number of scientists interested in the important field of hæm proteins. A. NEUBERGER.

Biochemical Aspects of Genetics. Edited by R. T. WILLIAMS. Biochemical Society Symposia, No. 4. [Pp. vi + 60, with 15 figures.] (Cambridge : at the University Press, 1950. 6s. net.)

THIS symposium consists of seven contributions, together with an introduction by Professor J. B. S. Haldane and a brief summary by Dr. A. Neuberger. The subjects treated cover a wide range, flower coloration (W. J. C. Lawrence), inborn metabolic errors (one paper from L. S. Penrose and one from C. Rimington), a comparison between the induction of mutations by radiation and by chemical agents respectively (J. G. Carr), mutations in *Neurospora* and other organisms (D. G. Catcheside), the discussion of genetic relations inferred from the biochemistry of bacteria and moulds (G. Pontecorvo) and a consideration of adaptive enzymes (J. Monod).

In its purest form the principle of classical genetics is that characteristics of living organisms depend upon permanent genes which do not change save by rare mutations but are normally only capable of various kinds of recombination and segregation. Some people are very reluctant to hear of any changes in these fundamental entities. There can be no doubt that ultimately the gene depends upon the molecular pattern of some part of the cell, and to other people it seems that such patterns are quite likely to be modified according to the conditions under which cells grow. The scientific problem would seem to be to establish by impartial experiments the precise degree of stability in any given case of the self-reproducing units. General statements on the subjects of environmental effects seem to arouse great prejudice—and not only on one side. And yet the whole of this symposium shows how the different views merge into one another, and that, while a degree of permanence in the fundamental structures is quite obvious from the mere fact that organisms reproduce their own kind, all kinds of subtle influences are at work to modify the absolute rigidity of this principle.

In these contributions there is at times a manifest desire to subscribe to the simple principle of " one gene one enzyme," or one biochemical function, but at the same time there emerges a clear—if not always explicit—recognition that this would be a rather gross oversimplification of the position. Inborn errors of metabolism have been ascribed to homozygous recessive genes. But in the contribution by L. S. Penrose we find the observation, " In the more variable conditions with incomplete manifestation or late onset we can suppose . . . that the failure of the necessary enzyme substance is only partial and that often the number of the steps in the causal chain between

gene and observed chemical effect is much greater." D. G. Catcheside remarks, " We can know about a gene only at the second or third degree removed, by what it does and by what alterations occur when a gene alters." Much space is devoted to chemically induced mutations which, whatever else may be said of them, remove the gene from the category of the eternal and unchangeable—and in this connection it is a pity that nothing was said about the relation between mutation and antibody formation (discussed elsewhere by Medawar). J. Monod remarks, " The occurrence of this phenomenon, generally referred to as enzymic adaptation, would seem to imply that certain types at least of specific molecules are produced only or mainly in response to a specific chemical stimulus, the agent of which is no other than the substrate of their activity." He says that he has studied the subject, " alternating between enthusiasm and suspicion." One wonders why either emotion is necessary. Is not the truth something like the following : that relatively stable structures become reproduced in living cells by complex patterns of reactions in which the individual velocity constants are subject to profound changes? These changes can fairly easily alter the relative proportions of the different structures and so affect biochemical properties. To produce changes, however, which are profound enough to impress the systematist, the chemical changes must be quite drastic and are very rare indeed. When reproduction of cells occurs by simple division, changes in enzyme proportions, environmental effects or destructive actions oh the key structures caused by ultra-violet light and chemicals are important reasons for variations in properties within the limits of an essential conformity to type. Where reproduction does not occur without chromosome mechanisms, changes due to segregation of important (and in a first approximation permanent) basic structures are more likely to dominate the picture.

Against this background the many interesting facts and views put forward in this symposium can be regarded dispassionately, and indeed a keynote of impartiality is struck by Prof. Haldane's (all too brief) introduction. Most of the work described should be of great interest both to chemists and to biologists.

<div align="right">C. N. H.</div>

Vitamins and Hormones. Vol. VII. Edited by ROBERT S. HARRIS and KENNETH V. THIMANN. [Pp. xii + 488, with 59 figures.] (New York : Academic Press, Inc., 1949. 58s. 6d. net.)

IN this, the seventh volume of the series, are included seven articles on the subject of Vitamins and five on Hormones. The titles and authors are as follows : " Vitamin P," by Harold Scarborough and A. L. Bacharach ; " Stereoisomeric Provitamins A," by L. Zechmeister ; " The Physiology of Thiamine," by B. C. P. Jansen ; " Niacin in Amino Acid Metabolism," by W. A. Krehl ; " Diet and Ageing," by Clive M. McCay ; " The Vitamin Requirements of the Growing Rat," by R. A. Brown and M. Sturtevant ; " Vitamin Requirements of the Guinea Pig," by G. J. Mannering ; " The Chemistry of Gonadotropic Hormones," by Choh Hao Li ; " The Chemistry and Physiology of Adenohypophyseal Luteotropin (Prolactin)," by Abraham White ; " Infra-red Spectrometry Applied to Steroid Structure and Metabolism," by Norman Jones and Konrad Dobriner ; " Alloxan Diabetes," by C. Cabell Bailey ; " The Chemistry of the Hormones of the Posterior Lobe of the Pituitary Gland," by R. L. Stehle ; " The Actions of

the Hormones of the Posterior Lobe of the Pituitary Gland upon the Circulation and the Secretion of Urine," by R. L. Stehle.

The articles concerning the vitamin requirements of the growing rat and of the guinea pig complete the series of surveys of the nutritional requirements of the more important laboratory animals, the requirements for primates other than man, chick and mouse, cotton-rats and hamsters having been reviewed in previous volumes. This series of articles will be of very great value and interest to laboratory workers of many kinds.

The article on " Vitamin P " discusses in a lucid manner the very tangled skein which has wound itself around the original interesting observation, of Armentano and his colleagues, that certain fruit extracts contained a factor, not ascorbic acid, that can increase capillary strength and reduce capillary permeability in man. While undoubtedly results of significance have been obtained, both clinically and in experimental animals, it still remains to be shown that such biological effects are those of a vitamin. The reviewers conclude that much of the recent work has employed doses whose size suggest a pharmacological action rather than that of a vitamin.

The article on the " Physiology of Thiamine," by B. C. P. Jansen, will be welcomed as one by the patriarch of this field. The review is, as one would expect, written authoritatively and clearly, and is a valuable statement by the acknowledged leader in this field.

Diet and ageing is a subject of great interest now that gerontology and geriatrics are of such significance in our changing life, and the review, by Dr. C. M. McKay, again is written by one who has himself supplied much of the original data on which our experimental knowledge is based.

On the question of Hormones, the article on the " Chemistry of Gonadotropic Hormones " by C. H. Li contains some original material of particular interest, and discusses with assiduity and judgment a subject that has at times been the most confusing in the whole hormone field.

The " Chemistry and Physiology of Prolactin " are ably discussed by A. White, while the review on " Infra-red Spectrometry of the Steroids," by Norman Jones and Conrad Dobriner, provides valuable new information and is also an extremely readable, but concise, summary of work on a method which is becoming of increasing value in the field of hormones.

" Alloxan Diabetes " is considered in a remarkably concise summary by Dr. C. C. Bailey, while finally the " Chemistry of the Hormones of the Posterior Lobe of the Pituitary Gland " from the pen of Dr. R. L. Stehle is of outstanding thoroughness and completeness.

It may be said of this volume as a whole that it maintains the high standard set by the previous volumes and will be a necessity for the library of those working on the subject of vitamins and hormones. The editors express a hope in the preface that the present volume will be found as useful as its predecessors, and of this there can be no possible doubt.

F. G. Y.

PHILOSOPHY AND HISTORY OF SCIENCE

The Power and Limits of Science. By E. F. CALDIN, M.A. [Pp. x + 196.] (London : Chapman & Hall, Ltd., 1949. 12s. 6d. net.)

MR. CALDIN's aim in this book is to reach a view of science and of its place among other mental activities. He finds that our evidence about the world comes from experience, with which reason can deal in different ways ; science

is one of them. The " method " of science is distinguished by its " subject matter " and its " point of view." These impose certain restrictions on it, and for complete knowledge it must be supplemented by other studies such as metaphysics, ethics, etc. Broadly speaking, the method of science is " inductive generalisation," and that of the other approaches to truth is " reflection."

Mr. Caldin writes clearly and says a number of well-known things very well, but one finds little evidence of more than superficial thought on the questions with which he deals. He repeatedly tells us, for example, that the subject matter of physics is " inanimate matter," which is profoundly inaccurate. If he were thrown over a cliff he would fall according to the physical law, although he might not become inanimate until he reached the ground. Biology is said to have a different " method " from physics, but how this (false) conclusion is reached is not clear. Again, what is the " reflection " by which we can reach metaphysical and ethical truths ? Suppose, as is the case, that the reflections of different people lead to different conclusions : what is the method of deciding between them ? This question is not touched, yet " reflection " is placed on a par with " scientific method." One might continue with such questions.

The trouble seems to be that Mr. Caldin has given too much time to reflection and too little to reading. " It is strange," he says in the preface, " that men do not more often examine the method of science, its field of work and point of view, in order to see what kind of knowledge it can in principle give us, and whether we must consult other sources." It is stranger still that, before writing this, he did not read more of what they have written. Although, apparently contradicting this statement, he gives a bibliography of 121 items (including some repetitions) and remarks that " many works of the first importance are omitted," one finds no mention at all of such names as Benjamin, Bridgman, Duhem, Frank, George, Jeffreys, Lenzen, Mach, Northrop, Pearson, Popper, Reichenbach, B. Russell, Schlick, in either index or bibliography, although their works, and those of several others that could be mentioned, are more to the point than many of the references cited. Consequently it is difficult to see what kind of reader would benefit from the book, for those who are sufficiently acquainted with the subject to avoid being misled by its imperfections will be already quite familiar with its sound points. This is a pity, for Mr. Caldin has evidently given much thought to the book and has the faculty of expressing his meaning simply and unambiguously.

                                                        H. D.

The Growth of Scientific Ideas. By WILLIAM P. D. WIGHTMAN, M.Sc., Ph.D. [Pp. xii + 495, with 43 figures, including 8 plates.] (Edinburgh : Oliver & Boyd, Ltd., 1950. 25s. net.)

THIS book is an attempt to introduce the well-grounded general reader to the history of science through a discussion of the dominant scientific ideas as they have developed and interacted through the ages. While not claiming to be a comprehensive history, it does, in fact, contain much information, clearly set out, concerning the growth of both physical and biological science.

The book is divided into two parts, of which the first, occupying two-thirds of the total length and entitled " Matter and Motion," assesses the implications and consequences of such developments as the Copernican

revolution, the invention of the telescope, the formulation of the laws of mechanics, and the rise of the wave-theory of light and of modern views on matter and energy. The author hopes that, through the critical study of the history of science, our school textbooks of physics will at last be freed from the confusion of ideas which has persisted from the age of Newton. The second and shorter section, on " Nature and Life," deals with the growth from classical antiquity of anatomy and physiology ; also with classification, the Cell Theory, evolution, bacteriology and much else besides.

Dr. Wightman believes that the present conflict in the scholastic world between classical and technological ideals can be most happily resolved by centring education upon the theme of science conceived as an historical and purposive human activity. His book is a notable contribution to the fulfilment of this aim. It is a work of scholarship, the fruit of wide reading and ripe consideration ; it succeeds in re-creating for the reader ways of thought no longer familiar, and it does not over-emphasise the political implications of the subject which obsess some able minds today. The illustrations are well chosen, and there are useful bibliographies and a chronological table.

There are a few points in the text calling for consideration. Copernicus was not a monk (p. 44) ; " Frauenhofer " (pp. 255 ff.) is more usually spelt, as in the index, " Fraunhofer " ; and the word " not " on page 316 (line 8) should more probably read " now." Accents are occasionally dropped from the Greek words quoted.

A. A.

MISCELLANEOUS

The Sea and its Mysteries : An Introduction to the Science of the Sea. By JOHN S. COLMAN. [Pp. 285, with coloured frontispiece, 16 plates, 36 figures and 1 folding map.] (London : G. Bell & Sons, Ltd., 1950. 12s. 6d. net.)

THE progress of the sciences is rapid and continuous and there was need for a new and up-to-date book on the science of the sea. Few more competent than John S. Colman could have been found to write it. The Sea and its Mysteries sets forth and discusses, in a semi-popular but nevertheless accurate and sound manner, the general principles, methods and findings of the marine sciences.

It ranges over a wide field from the " shape of the sea " to " life in the depths," from the formation of coral reefs to a general survey of oceanographical and marine biological research. Throughout all this diversity of subject matter the author maintains an easy and readable style that will prove attractive to both amateur and specialist readers. In short, this is a first-class book with few faults that cannot easily be corrected in a future edition.

G. A. STEVEN.

Science News 16. Edited by J. L. CRAMMER. [Pp. 176, with 16 plates and 37 figures.] (Harmondsworth : Penguin Books, Ltd., 1950. 1s. 6d. net.)

THE variety of topics which the present number of Science News covers precludes any systematic review, and so a series of stimulating and entertaining articles, including the second part of Prof. Hartridge's paper on

" Human Colour Vision," and ranging from " Making Chemicals from Petroleum," in which C. L. Gilbert offers a valuable introduction to one of the major branches of chemical engineering, to " A Theory of Chess and Noughts and Crosses," by D. W. Davies, whose essay in applied mathematics has a clarity which must appeal even to those who feel that " rational play " can scarcely be play of any sort, must all be passed over without further comment.

In the first article of the volume, " Recent Work on Mesons," Terence Price writes closely to his title, and in doing so invites criticism on two scores. In the first place, his subject is notable as one in which broad ideas, relevant to the whole structure of physical science, are developing rapidly. The general appreciation of the situation must surely be the goal of the average reader, but he will find the task of getting there for himself, from the strictly limited experimental topics about which Mr. Price writes, extraordinarily difficult. Secondly, what exactly has the writer in mind when he states that " . . . the Berkeley cyclotron is an instrument capable of producing mesons for research in numbers one hundred million times greater than those available in cosmic rays " ?   One of the interesting problems of the application of machines such as Mr. Price describes, and the much larger ones now under development, is precisely that of making at all efficient use of the nominal particle output.   Mr. Price himself shows how many of the experiments already undertaken with low energy artificial mesons are technically limited, in exactly the same way as are comparable cosmic ray experiments, by the necessity of working up individual photographic emulsion records.   In the present simple experiments this limitation does not invariably intervene, but it seems likely that, when the more energetic meson processes are brought into the scope of artificial bombarding particles, more than ever it will be necessary to return to the detailed analysis of records of single encounters, for example in photographic emulsions.   Of course there has been worth-while gain wherever it has proved possible to work with artificial particles, but the advantage is much more often ten or perhaps a hundred times less than the astronomical figure which is suggested here.

<div align="right">J. G. WILSON.</div>

The Scientific Journal of the Royal College of Science, Vol. XIX, 1949. [Pp. vi + 163, with 42 figures.] (Paper covers, 7s. 6d. net ; cloth, 10s. net.)

THIS entertaining volume contains a selection of the papers read before the Natural History Society and the Mathematical and Physical Society of the Royal College of Science, and the Imperial College Chemical Society.   If you are interested in vitamins or visual research, phosphorus compounds or photographic emulsions, in electrochemical research or the scientific study of European witchcraft, here are to be found summaries of the most recent research and expositions of contemporary ideas.   If you are not already interested in these topics, or in snails and slugs, in spiders, in the impact of modern physics on the Christian faith, in non-Euclidean geometry, or how chemically inert substances may influence the action of drugs—then be assured that your curiosity will inevitably be aroused, for in these brief and varied papers the subject matter is invariably well-chosen and presented in a way which is always clear, often masterful and sometimes even exciting. It is especially fitting that the book opens with a brief appreciation of Sir Ian Heilbron which contrives to paint a vivid picture of the great scientist,

teacher and administrator who did so much to foster research at the Royal College of Science while he occupied its Chair of Organic Chemistry.

H. I.

A List of British Scientific Publications reporting Original Work or Critical Reviews. The Royal Society Information Services Committee. [Pp. 95.] (London : Cambridge University Press, for the Royal Society, 1950. 2s. 6d. net.)

THE Royal Society, in issuing this valuable booklet, has restricted the range to scientific publications as distinct from trade papers, news journals and publications of Government departments. The criterion for inclusion is whether the journal contains " a substantial proportion of original work or critical reviews." Even with this limitation no less than 212 publications are described. The information is given in alphabetical order of publishing societies or organisations, with an index of the names of the journals and a subject index. Each entry includes a description of the content of the journal, what indexes are issued, the frequency of publication and the price, the volume number, the number and size of pages in each issue, whether summaries of the papers are included, if advertisements are accepted, where and how directions to authors may be obtained, and the addresses of the editor and of the publishing organisation.

From a reading of the introduction, it is apparent that the booklet is somewhat experimental, and criticism is expected. In such a list, one should not need to consult the index to find a particular journal, or alternatively have previous knowledge or " second sight " that, for example, the *British Journal of Cancer* is published by Messrs. H. K. Lewis. The value of the brochure would be enhanced by rearrangement of the contents to give an alphabetical list of journals, with indexes of scientific societies and publishing organisations. In spite of the drawback mentioned, the book is a veritable mine of information concerning scientific periodicals, and the Royal Society deserves the thanks of the community for undertaking such a labour of love. May we hope that it will be followed by a companion volume containing similar information concerning scientific news journals, trade publications and those of Government departments ?

H. S. ROOKE.

English Index to Soviet Medical Periodicals available in London Libraries. Vol. I, 1945–1947. Edited by DONOVAN T. RICHNELL, B.A., F.L.A. [Pp. xii + 93.] (London : H. K. Lewis & Co., Ltd., 1950. 20s. net.)

WITH part of the residuum of the funds of the Joint Committee for Soviet Aid, the Medical Committee of the Society for Cultural Relations with the U.S.S.R. has sponsored the production of this index.

The form of the entries is based on that adopted by the *Index Medicus*, to which it is complementary.

The present volume covers eighteen important Soviet Medical Journals issued between 1945 and 1947 which are located in four London libraries. The precise location of particular numbers is stated in Section IV of the introduction. It is understood that the Library of the Royal Society of Medicine can be approached for microphotographic copies of the articles listed in the index.

It is hoped that an additional volume covering the years. 1948–49 will be published later this year and subsequently annual issues if the publication receives adequate support.

Even before 1939, Soviet medical literature was never fully indexed for the English-speaking world. *The World List of Scientific Periodicals 1900–1933* merely listed the indigenous name of the Russian Journals without indicating in numerous cases library sources. Neither the *Index Medicus* nor the *Current List of Medical Literature* has been able to cover Soviet literature since 1945.

Although the present list of journals is not as complete as one would like, the sponsors are to be congratulated on a praiseworthy attempt and on the presentation. The pages reflect credit on the editor and the printer alike. Its uniqueness will make it indispensable in any worthwhile Medical Library.

C. C. N. V.

BOOKS RECEIVED

(Publishers are requested to notify prices.)

The Scientist's Ready Reckoner. Logarithmic Tables for all those engaged in physical and biological sciences. By W. Roman, Ph.D., A.F.Inst.Pet., Chief Analyst of Petrocarbon, Manchester. The Hague : Dr. W. Junk, Publishers, 1950. London Agents : Wm. Dawson & Sons, Ltd. (Pp. viii + 142.) 15s. net.

An Introduction to the Theory of Statistics. By G. Udny Yule, M.A., F.R.S. formerly Reader in Statistics, University of Cambridge, and M. G Kendall, Sc.D., Professor of Statistics, University of London. Fourteenth edition. London : Charles Griffin & Co., Ltd., 1950. (Pp. xxiv + 701, with 62 figures and numerous tables.) 34s. net.

Introduction to the Theory of Probability and Statistics. By Niels Arley, Assistant Professor of Physics, Institute for Theoretical Physics, University of Copenhagen, and K. Rander Buch, Assistant Professor of Mathematics, Institute for Applied Mathematics, Denmark Institute of Technology. Applied Mathematics Series. New York : John Wiley & Sons, Inc. ; London : Chapman & Hall, Ltd., 1950. (Pp. xii + 236, with 21 figures.) 32s. net.

Acceptance Sampling. A series of papers and discussion delivered at the 105th Annual Meeting of the American Statistical Association at Cleveland, Ohio, on January 27, 1946. Washington, D.C. : The American Statistical Association, 1950. (Pp. iv + 155, with 11 figures.)

Astronomy of Stellar Energy and Decay. By Martin Johnson, D.Sc., F.R.A.S., F.Inst.P. With a foreword by Lt.-Col. F. J. M. Stratton, D.S.O., F.R.S. London : Faber & Faber, Ltd., 1950. (Pp. 216, with 4 plates and 22 figures.) 16s. net.

Interplanetary Flight. By Arthur C. Clarke, B.Sc., Assistant Secretary, British Interplanetary Society. Technical Trends Series. London: Temple Press, Ltd., 1950. (Pp. viii + 164, with 16 plates and 15 figures.) 8s. 6d. net.

Practical Applications of Spectrum Analysis. By Herbert Dingle, D.Sc., formerly Professor of Natural Philosophy, Imperial College of Science and Technology. London: Chapman & Hall, Ltd., 1950. (Pp. x + 245, with 19 plates, 37 figures and 8 tables.) 40s. net.

An Introduction to Luminescence of Solids. By Humboldt W. Leverenz, Radio Corporation of America, Princeton, N.J. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1950. (Pp. xvi + 569, with 143 figures, 23 tables and chart in pocket.) 96s. net.

Einführung in die mikroskopischen Untersuchungsmethoden. By Heinz Appelt, Dr. Med., Leiter der chirurgischen Abteilung des Stadtkrankenhauses Leipzig-Markkleeborg. Potsdam: Akademische Verlagsgesellschaft Athenaion, 1950. (Pp. xvi + 228, with 16 plates and 251 figures.) DM16.—.

Sound. By Frederick G. Mee, M.A., B.Sc., Senior Physics Master, Sherborne School. London: William Heinemann, Ltd., 1950. (Pp. x + 171, with 5 plates and 85 figures.) 8s. 6d. net.

Atomic Physics. By Wolfgang Finkelnburg, Ph.D., formerly Professor of Physics, University of Strassburg. Translated from the revised German edition by George E. Brown, M.Sc. New York, Toronto, London: McGraw-Hill Book Co., Inc., 1950. (Pp. x + 498, with 226 figures and 16 tables.) 55s. 6d. net.

Atomic Energy. Edited by J. L. Crammer and R. E. Peierls, C.B.E., F.R.S. Revised and enlarged edition of Science News 2. Harmondsworth: Penguin Books, Ltd., 1950. (Pp. 200, with 16 plates and 24 figures.) 1s. 6d. net.

The Development and Future of Nuclear Energy. By Sir John Cockcroft, C.B.E., F.R.S. The Romanes Lecture, delivered in the Sheldonian Theatre, June 2, 1950. Oxford: at the Clarendon Press, 1950. (Pp. 23.) 2s. net.

Trilinear Chart of Nuclear Species. By William H. Sullivan. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1949. 20s. net.

Super-Regenerative Receivers. By J. R. Whitehead, B.Sc., Ph.D., F.Inst.P., A.M.I.E.E., S.M.I.R.E., Principal Scientific Officer, Telecommunications Research Establishment, Ministry of Supply. Modern Radio Technique Series. Cambridge: at the University Press, 1950. (Pp. xiv + 169, with 78 figures, including 4 plates, and 9 tables.) 21s. net.

Science via Television. By Lynn Poole. Baltimore: The Johns Hopkins Press; London: Oxford University Press, 1950. (Pp. xii + 198, with 23 plates and 1 figure.) 28s. net.

A Text-Book of Inorganic Chemistry. By J. R. Partington, M.B.E., D.Sc., Professor of Chemistry in the University of London, Queen Mary College. Sixth edition. London: Macmillan & Co., Ltd., 1950. (Pp. x + 996, with 394 figures.) 25s. net.

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